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GRAVITY CHANGES IN AIRCRAFT AND SHIPS

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Introduction

Subgravity and Zero-gravity conditions have been studied intensively during the last few years, because we already find these conditions in high-speed and high-altitude flight, and the question is whether they can provoke disorientation or troubles of neuro-muscular co-ordination. If so, the safety of the pilot and the crew of an aircraft or space-vehicle would necessarily be endangered.

Theoretical and experimental data concerning this matter have been published by H. G. Armstrong, [17], E. R. Ballinger, [1,13] O. Gauer,[7] S. J. Gerathewohl[8,9,10,21] A. Graybiel,[20] F. Haber,[12] H. Haber,[7,11,12,17,23] J. P. Henry,[13] P. M. Maher,[13] D. G. Simons[13,24] H. Strughold,[16,17] and H. J. A. von Beckh.[2,18,19]

The modest contribution of the author to this subject consisted of experiments in diving and parabolic flights and recently also in experiments of gravity changes in ships.

The first mentioned studies, already published in the *Journal of Aviation Medicine*[18] and in the Proceedings of the IV International Congress of Astronautics,[2] are included here, as they have not already been previously published in this *Journal*.

Changes of Gravity in Aircraft

(*a*) *Experiments with Animals*

Since 1951, the author has been studying the behaviour of certain species of Chelonia, notably *Chrysemis ornata* and *Hydromedusa tectifera*, which are found on parts of the South American Continent. These turtles would seem to be especially suitable for studies of orientational behaviour and muscular co-ordination because of their ability to move under water with extraordinary speed and skill in all directions during their quest for food. The animals belong to an extremely voracious class of water turtles. Under normal gravity conditions, i.e. on the ground or in horizontal flight, they strike like snakes at their food, projecting their S-shaped necks with pin-point accuracy at the bait. They will also snatch a piece of meat hanging from the mouth of another animal. In fact, when they are hungry, they try to pull out the bait which is already in the mouths of other turtles.

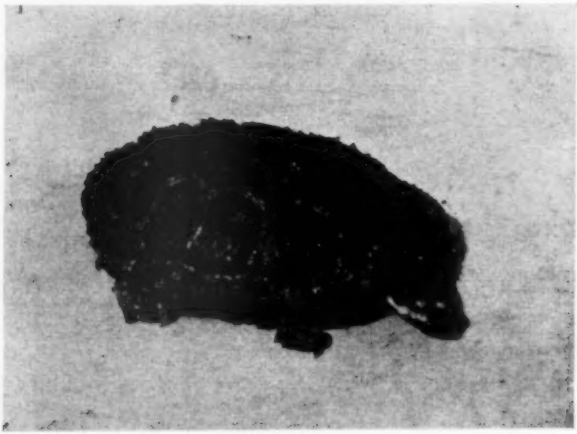

FIG. 1. *Hydromedusa tectifera* on the ground in a defensive position. The long S-shaped neck is partly covered by the shell.

FIG. 2. *Hydromedusa tectifera* attacking; the animal strikes at the bait.

For behaviour studies under sub- and zero-gravity conditions several normal animals and one turtle with a permanent injury of the labyrinth were used. This animal had been left for some days by accident in an over-heated aquaterrarium. As a result, he showed a complete loss of orientation, which was particularly obvious in the water. Offered a piece of meat, this *Hydromedusa tectifera* tried to attack it with strong but unco-ordinated movements that contrasted strangely with his normally smooth, swift locomotion. Moreover, when striking, the head of this animal would pass over, under, or to one side of the bait. After two weeks, the turtle slowly began to recover. The improvement was shown by his movements, and later also by his aim in taking the bait. At the end of three weeks from the time of accident, the animal was able to eat normally. I concluded that this turtle had suffered a permanent labyrinthine injury from the extreme thermic irritation to which he had been exposed, but that he had then learned to compensate for his loss of labyrinthine cues by developing his visual orientation.

In order to test the permanence of the injury, I tied a hood over his head. The animal then displayed complete disorientation again, both in and out of the water. He did not even try to displace the hood, as did the control animals. Nor did the latter show any orientation difficulty when they were subjected to the same experiment.

Experiments in the air were then begun with this "adapted" animal, with other *Hydromedusa tectifera*, and with the two *Chysemis ornata*. The animals were carried in a cylindrical jar, open at the top and filled with water. They were subjected to vertical dives that produced sub-gravity and zero-gravity conditions for as long as seven seconds. During these, the animals were offered samples of meat, either individually with pincers or by pushing the bait into the jar. The latter procedure was extremely instructive because of the fight that followed among the animals in their attempt to seize the food.

In the transition from horizontal to vertical flight, some brief negative acceleration was produced. At this time the water (and occasionally the animals with it) would rise up, forming an ovoid cupula to a height of 20 or 30 cm. above the top of the jar. However, most of the water would flow back when the jar was lifted to the same height. The acceleration was measured with g-meters in each of the three axes of the plane. These were specially prepared to record values from zero to plus 1 g. or minus 1 g.

Results

The results of these flights may be summarized as follows. Only the *Hydromedusa tectifera* without labyrinthine functions, but visually adapted, behaved with complete normality under sub- and zero-gravity conditions. He moved with speed and accuracy, and demonstrated the same skill and ease in eating as on the ground.

The other three turtles, by contrast, moved only a little, quite slowly, and insecurely. They were unable to attack the offered bait. Even pieces of meat that were placed directly in front of their mouths could not be taken, due to their inability to project their heads in an aiming movement. Yet it was obvious to the observer that they were hungry and were doing their best to

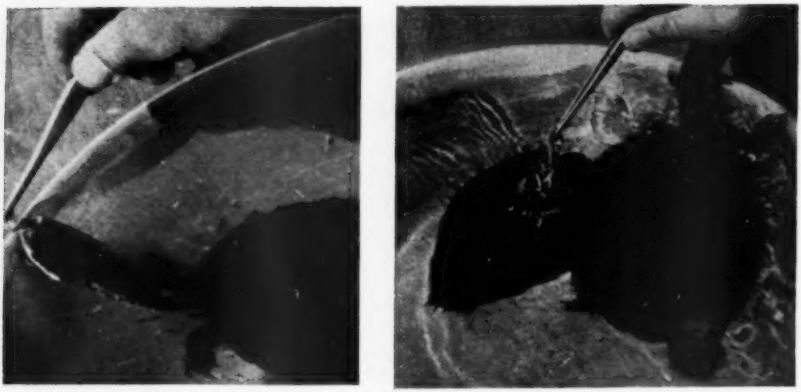

FIG. 3. (*Left*) *Hydromedusa tectifera* in the cylindrical jar striking at the bait. (*Right*) Shows the voracity of these turtles: the bait is offered to the *Chrysemis ornata*. (*Background*) The Hydromedusa noticed that the author has in the palm of his hand more meat for other baits and strikes at it.

strike at the bait. Their failure to take it followed the same pattern that had been observed in the case of the injured animal before adaptation took place. After the return to horizontal flight, all the animals behaved normally. While these symptoms of disturbed orientation and co-ordination gradually diminished after 20 to 30 flights, the improvement was by no means so great that the normal turtles reached the same mobility and eating skill as shown by the "adapted" animal.

Discussion

The experiments described above demonstrate once more that the senses of equilibrium, vision, and kinesthesis provide the means of orientation and co-ordination under normal or sub-gravitational conditions. During sub-gravity, all the uninjured animals showed considerable difficulty in both orientation and co-ordination. This was exhibited by their inability to aim the neck and head toward an offered bait. The same animals, disturbed by the absence of weight during zero-gravity, became more or less adapted after a certain number of dives (20 to 30).

The animal without labyrinthine functions had experienced orientational troubles of a similar kind immediately after the injury, but had become adapted in the following three weeks. During all zero- and sub-gravity flights, he behaved in a completely normal way.

Magnus and de Kleyn (1924) had demonstrated previously that some of the higher animals, such as cats and monkeys, are able to walk and climb in a normal fashion several days after labyrinthectomy. Moreover, it has been observed that they can even jump, landing precisely on the target.[14] This proves that they "aim steadily at their target by means of optical postural reflexes at first, then bring the body into a corresponding position." The two

authors thus cited found no lasting decrement of muscle tonus in these operated animals. Where it was found at all, it disappeared after a while.

Similarly, the *Hydromedusa tectifera*, according to my observations, executes his movements with no less force after labyrinthine injury, but with impaired co-ordination. After adaptation, he then behaved with complete normality on the ground, and he outperformed by far the normal animals under sub-gravitational conditions. This paradox can easily be explained by the dominant role of the optical sense in orientation. It also appears that the labyrinth has only a partial function in the general regulation of tonicity, and may be compensated for by other senses without serious difficulty when the need arises.

It should be noted, though, that in our case adaptation occurred under normal gravity conditions. A decrement of muscle tonus might possibly be found when gravity and weight are reduced or entirely removed for long periods.

Finally, it may be mentioned that the labyrinthectomized animal in the experiments described by Henry, Ballinger, Maher and Simons (1952) also did better than the normal animal during sub- and zero-gravity conditions. However, no disturbances of co-ordination were observed in those experiments. Hence, it seems to me that water animals of the species employed in my tests are especially suitable for studies of orientation and motor co-ordination in the gravity-free state. The reason is that they ordinarily move in three dimensions, as most animals do only under exceptional circumstances, and they can be impelled to demonstrate their motor efficiency when hunger is used as the motivating drive.

(*b*) *Experiments with Human Subjects*

A series of experiments in visual orientation and muscular co-ordination of human subjects under gravity-free conditions was also performed. In these tests, the subject had to draw crosses in seven small squares, which were arranged diagonally from the left top corner to the right bottom corner of a sheet of paper (21 × 21 cm.) attached to the instrument panel of an airplane. No support was available for the hand of the subject because of the distance between the seat and the panel. The subject was held by his shoulder belts firmly in his seat.

A fighter 'plane with two seats was used in these experiments. The 1,500-h.p. engine gave a diving speed of about 365 knots. Two kinds of experiments were made. In the first, each subject took the test (1) in horizontal flight, (2) during radial acceleration in the direction from head to feet, and (3) during the dive, under sub-gravity and zero-gravity conditions. The tests were made both with eyes open and with eyes closed; and two different test forms were employed.

In the second type of experiment, the effect of post-acceleration weightlessness on orientation was investigated. The pilot dived from about 10,000 feet to about 7,200 feet and pulled out of the dive rather abruptly. This manœuvre produced a positive acceleration of about 6.5 g., causing the subject to black out. (The pilot was protected against the effects of high acceleration by a crouching position.) Immediately after the pull-out, the aircraft was flown along the ascending arc of the parabola, in which aerodynamic forces are equalized by the power of the engine. In this way, post-acceleration weightlessness was achieved for about 12 seconds.

FIG. 4. One of the test persons (a Medical Orderly) fixed on a chair screwed to the floor, looking with his fixed head towards a pin-point of light.

Results

In the first experiment, the following observations were made:—

1. During horizontal flight, with eyes open, the crosses were placed in the squares without difficulty.

2. During horizontal flight, with eyes closed, the crosses were placed diagonally in the prescribed manner with only slight irregularity due to the lack of visual control.

3. During zero-gravity, with eyes open, drawing the marks became difficult. They were made inaccurately, and deviated from the established pattern, although a diagonal direction was generally followed. This, of course, was due to the visual control.

4. During zero-gravity, with eyes closed, deviation from the diagonal direction was so pronounced that it could not be attributed solely to the lack of visual control. The subjects experienced great difficulty in placing the crosses in the squares.

After the third cross was made, a typical deviation of about 90° toward the right-hand top corner was noted in most cases. However, the execution of this test improved after several flights. The person with the longest record in instrument flying showed a very remarkable improvement already after the second flight.

A further decrease in accuracy was found after the well-tightened safety and shoulder belts had been replaced by a loosely adjusted seat belt alone. Besides visual control and positional stability, another psychological factor seems to influence the performance of this test.

The results of the second type experiment may be summarized as follows:—

1. During post-acceleration weightlessness, orientation was extremely affected. The disturbance occurred shortly after the beginning of the gravity-

free state. The subject had the sensation of flying in an inverted position, although no negative acceleration had been present.

2. The black-out lasted longer than after a normal pull-out. Vision was not restored until the 'plane entered the descending arc of the parabola.

3. Only after the fifth second of weightlessness could the drawing with visual control be started. The crosses then showed the same deviation from the diagonal direction that had been found under sub- and zero-gravitational conditions.

Discussion

Although the interpretation of our results is hampered by the relatively small number of experiments, some tentative conclusions may be drawn. Von Diringshofen attributes the deviation from the line in the drawing test to the dominant tonus of the elevating arm muscles during the state of weightlessness. It also seems to me that the muscular equilibrium of the arms can be better maintained during increased acceleration than with decreased gravity. This observation is in accord with the Weber-Fechner law, as suggested earlier by Gauer and Haber (1950).[7]

Garten (1917) and Strughold (1950) have already pointed out the importance of the tactile sense in maintaining orientation during flight.[6,16] In this connection, I would like to add that disorientation, due to incorrect labyrinthine cues, can be prevented by the toxic effect of streptomycin on the vestibular apparatus. This effect has been demonstrated by Berg (1949) and by Northington (1950).[3,15]

So far as visual orientation is concerned, disturbances in the transition phase from the normal to the zero-gravity state may take the form of optical illusions as suggested earlier by Gerathewohl.[8,9,10] It seems possible that an illusory effect of this sort may be partly responsible for the deviations in the drawing tests.

As von Diringshofen suggested (1952), the serious disturbances during post-acceleration weightlessness may be caused by poor reaction of the haemostatic regulators in the circulatory system. These are normally adjusted to 1 g.[4] Moreover, relaxation of the muscles (fall reflex) may cause delay in the flow of blood from the lower parts of the body to the right ventricle (Magnus and Kleyn, 1924) with the same result.

The practical side of our problem should also be mentioned here. A pilot, pulling sharply out of a dive, may experience greying or blackout. In order to recover quickly, he may push the stick so far that the airplane enters a parabola. In this event, the pilot may become weightless, and his loss of sight and orientation caused by the increasing *g's* may even be prolonged.

Such a situation could occur when the 'plane is manœuvering in an air battle. Combinations of dives and pull-outs into parabolas do occur when fighter craft make, for instance, highside gunnery runs on bombers. The attacking 'plane penetrates the fighter defence by diving from a high altitude, makes its pass at the bomber from below as he pulls out, then evades the bomber's guns by another dive. In evolutions of this kind during World War II, pilots frequently experienced negative accelerations, weightlessness, and thereby disturbances of vision.

Not only because of its theoretical interest and its application in the future to space-flight, but also because it has an immediate bearing on combat flying, the author intends to continue experiments on this problem. It is planned to improve the methods and equipment. Various positions of the head will be used to compare the reactions of the otoliths under sub- and zero-gravity conditions. The optical illusions, predicted by Gerathewohl (1952) during changes of acceleration in the sub-gravity state, also will be investigated further.

Changes of Gravity in Ships

The movements of a ship and of an aircraft are similar because they depend on the undulations and turbulence of the medium in which they float: (1) the "rolling," which is a transversal movement from port to starboard and vice versa; (2) the "lift," which is an ascending and descending of the entire craft, whose longitudinal axis will stay parallel to the trajectory during this movement; (3) the "pitching," which is a movement with a transversal axis, which causes the bow and the stern to rise alternately.

These three typical movements will combine with the forward movement of the craft and also among themselves. So all kinds of linear, radial and angular accelerations and decelerations may be produced.

In special cases (rough sea and facing wind), in places near of the bow, remarkable undulating and rhythmical changes of gravity can be observed, which can be used for experiments.

The author realized some preliminary studies during Atlantic crossings, trying to observe the optical illusions predicted by Gerathewohl during changes of acceleration in the subgravity state.

The subjects were placed in a dark room near the bow of the ship on chairs screwed to the floor and with their heads fixed on head supports by means of bandages. A pin point of light was placed at a distance of between 2 to 5 metres. For registration of gravity changes accelerometers were used which were prepared *ad hoc* by the electrical engineer of the ship, to whom the author is indebted.

Of seven persons observed, three were absolutely certain that they had experienced the optical illusion of the displacement of the luminous point in an up and down direction respectively.

We must mention that D. G. Simons[25] and S. J. Gerathewohl[22] are actually performing experiments with T–33 and F–86 airplanes. They had the kindness to inform me, that they have up to date registered valuable and important data about neuro-muscular co-ordination by experiments using also drawing tests. On the other hand they intend to prove objectively the above-mentioned optical illusions using a faintly illuminated system of co-ordinates, which would permit a relation between intensity of gravity changes and the observed displacement to be established.

The publication of the results of these interesting experiments will be very important for the studies of the behaviour of human beings in abnormal gravity conditions, which is an important space-flight problem.

Concerning the preliminary studies of gravity changes on ships, the author believes, that in spite of the fact that a pure Sub- or Zero-gravity in these

conditions is obtainable only in exceptional cases, the advantage of these experiments lies in their easy realization and in the possibility of making numerous experiments simultaneously with different subjects.

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A FAMOUS RUSSIAN ENCYCLOPAEDIA ON ASTRONAUTICS—3

By G. V. E. Thompson, B.Sc., A.R.C.S., F.R.I.C., L.I.M.

SUMMARY

The previous articles in this series on Professor N. A. Rynin's *Mezhplanetnye Soobshcheniya* (see *J.B.I.S.*, 1954, **13**, 193, 301) reviewed the first six books of this nine-volume work and part of Book VII. This concluding article deals with the remaining sections; an appendix gives the bibliographical details.

VII. Tsiolkovskii—(*contd.*)

The first chapter of Volume Seven, having given a brief biography of Tsiolkovskii, the second gives a general survey of his chief work in fields other than astronautics. These included aerodynamic experiments, details of the model metallic dirigible, balloons, a design for an aeroplane (drawn up in 1895), and a reactive car (1927). This last design was for a railway—car or coach without wheels, but supported on a thin film of air—a device which may shortly find application for speed-boats, but which obviously presents great difficulties where land vehicles are concerned (the principle is similar to that of the hydrodynamic lubrication of bearings). In a book published in 1895 entitled *Dreams about the Earth and Heavens and the Effects of Universal Gravitation*, Tsiolkovskii discussed astronautical experiments which should be carried out on human beings, and also means of transport on asteroids.

Chapter Three is concerned with Tsiolkovskii's rocket projects, and opens with an introduction written by him on May 14, 1927, in Kaluga, at Prof. Rynin's request. In this, Tsiolkovskii indicates how he thinks interplanetary travel will come about and lists the names of rocket pioneers in Russia and elsewhere. He also points out that until his own work no one had thought about applying the principle of the rocket for travel above the atmosphere. This is perhaps not 100 per cent. correct—a few years previously, Hermann Ganswindt had made some proposals for space travel—but Ganswindt does not appear to have understood clearly the principles involved and Tsiolkovskii was certainly the first to tackle the mathematics of the subject.

After Tsiolkovskii's introduction, various quotations from his publications are given, followed by illustrated descriptions of ten rocket designs. These are of necessity excessively crude, usually showing a section divided up into areas representing the various items of equipment or facilities. They are obviously not intended to be engineering drawings suitable for constructing a working spaceship. For that matter, neither would it be possible to construct working spaceships from the highly detailed designs advanced to-day, by say, von Braun or others, even although these look much more plausible. Many more years of calculation and experimentation are needed. Even if Tsiolkovskii's illustrations seem naive to our eyes, we can find little fault with him for his choice of propellants—usually liquid oxygen with liquid hydrogen or hydrocarbons.

The first design (1903) shows a streamlined shape divided up into a long conical combustion chamber, propellant tanks, and a living compartment. In the second type (1914) a much longer combustion chamber is entwined in

serpentine coils; it looks a highly dangerous piece of apparatus. Tsiolkovskii evidently had second thoughts about it, for in 1927 he wrote against this type of construction. His third design (1915) published in a book by Perel'man, another well-known Russian rocket pioneer, is essentially the same as the first with the exception of the addition of propellant pumps and a pipe to allow vapour to escape from the liquid oxygen storage tank. The fourth and fifth rockets are intended to depict vessels constructed in the year 2017, the former being merely a bomb-like object 20 metres long and 2 metres in diameter, but the latter a most formidable device. The rocket itself is merely 100 metres long by 4 metres in diameter, but attached to it is a greenhouse 500 metres long. An alternative scheme has a greenhouse 1,000 metres long, complete with baths and toilets. These extraordinary greenhouses were, of course, intended to provide food for the crew of 20. No details are given of the sixth rocket, except that it was a portable type intended for use by helmetted persons outside a spaceship. Tsiolkovskii was evidently concerned not only with the mere theoretical possibilities of crossing space, but also with some of the practical problems which would arise. This is further shown in his plan for a wheeled rocket vehicle for travel on the Moon. His eighth design was drawn up about 1927, particulars of it being quoted by Shershevskii in an article in *Flugsport*, 1927, p. 425, and in his book *Die Rakete* (1929). About this time Tsiokovskii himself published suggestions for the construction of laboratories for testing rockets (in his book *Kosmicheskaya Raketa; Opytnaya Podgotovka—The Cosmic Rocket; Experimental Preparation*).

Rynin describes the ninth project (1926) in more detail, and in many respects it is the most interesting of all. The main body of the vessel—intended as a spaceship—is roughly cigar-shaped, being 20 metres long and 1–2 metres wide at the greatest section. The combustion chamber was quite small, with a conical throat of 4 cm. diameter, but a nozzle about 10 metres long subtending an angle of 1–5°. Behind the end of the nozzle were placed control surfaces similar to those of an aeroplane; Tsiolkovskii intended these for use not only in the atmosphere, but also to act on the exhaust gases of the rocket; this was, of course, the control method eventually adopted for V-2 (and other guided missiles since). He suggested that several of these rockets could be placed side-by-side and joined together to make a composite vehicle. His tenth project (1929) is even more complicated, since it concerns travelling in a "train" of rockets. There would actually be 15 rockets in the train, grouped into five sets one behind the other, each set containing three rockets joined abreast of one another. The leading set would be fired first; when all its propellants were burnt, it would be dropped back to Earth and the second set would take over. The proposed vehicle is thus nothing more than a very elaborate form of step-rocket. Tsiolkovskii adopted this design in preference to those used to-day (in which the rearmost step is burnt first) because he wanted the structures to be under tension rather than compression. In present-day step rockets, such as "Bumper," or in the modern conception of a step-rocket spaceship, each successive step is less massive than its predecessors and the existence of compressive stresses is no difficulty. In Tsiolkovskii's scheme, however, it is evident that serious trouble would be experienced were tail-drive to be adopted

for the "train" as a whole. Rynin does not mention whether the links between the various component rockets were supposed to be rigid, but they certainly would have had to be so if tail drive were to be used, and even then it is likely that the whole construction would fail by buckling. Of course, this does not mean that the design as it stands is workable; apart from the more obvious defects, the use of a front drive necessitates the firing of the motors in pairs with their exhaust gases and thrusts acting at an angle to the centre line of the "train"—i.e., they are not operated at maximum efficiency. To round off this chapter, mention is made of a rocket aeroplane capable of a speed of 3,600 km./hr., proposed by Tsiolkovskii in 1930.

Under the heading "Theory of Rocket Flight," Rynin has summarized the theoretical work published by Tsiolkovskii over the period 1903–26, in eight articles and books. Part of this had been given previously in Book V (see *J.B.I.S.*, 1954, **13**, 303). Thus, the first few topics dealt with are: the principle of rocket flight, flight of a rocket in an environment without gravitation or atmosphere (a deduction of the relation between exhaust velocity, mass ratio, and the final velocity of the vessel, together with the results of some calculations), and vertical, horizontal and oblique flight in a gravitational field. The additional subjects discussed here are: the mathematics of stopping a rocket in a gravitation-free space and in a gravitational field; escaping from and landing on the Earth, the Moon and asteroids; the work done against gravity in escaping from a planet; the calculation of escape velocity and the time of flight; the resistance of the atmosphere; and rocket orbits. In the last-mentioned section, Tsiolkovskii explained the velocities required for circular, elliptical, parabolic and hyperbolic orbits. Finally, Rynin quotes five theorems propounded by Tsiolkovskii in 1914 in a brochure "Investigation of World Spaces by means of Reactive Devices":—

THEOREM 1. Assume that the force of gravity does not decrease on removal of a body from a planet. Assume that this body is raised to a height equal to the radius of the planet; then the work performed is equal to that which would then be necessary for completely overcoming the force of gravity. (i.e., the potential energy of a body at a height of one radius is one-half that of the body at infinity.)

THEOREM 2. In a gravitation-free space the final speed of the rocket for a constant direction of thrust is independent of the force and order of intensity, but only depend on the quantity of propellants (in relation to the mass of the rocket) and also on the nature and construction of the combustion tube.

THEOREM 3. If the quantity of propellants is equal to the mass of the rocket, then almost half the energy of the propellants is transferred to the rocket.

THEOREM 4. When the mass of the rocket plus propellants increases in geometric progression then the speed of the rocket increases in arithmetical progression. For example, when the mass increases in the ratios 2, 4, 8, 16, 32, 64 . . . then the speed increases in the ratios 1, 2, 3, 4, 5, 6.

THEOREM 5. In a gravitational field, for example on Earth, in the vertical ascent of the rocket, part of the energy of the propellants is lost, and this

part is greater the nearer the thrust of the exhaust gases is to the weight of the rocket.

It will be apparent that the last four of these theorems are all implicit in the fundamental equation of rocket flight: velocity = exhaust velocity × (natural logarithm of mass ratio).

The final chapter is a summary of a book published by Tsiolkovskii in 1926, having the same title as his 1914 brochure. It apparently contained some additions and revisions to the theory mentioned above. Thus he had changed his opinions concerning "space-guns" and now thought they might prove useful (possibly in the form of an electromagnetic launcher); the results of some calculations are reproduced. Other subjects dealt with are the energy of the propellants, a more precise calculation of air resistance, the most advantageous angle of flight, the effect of the curvature of the Earth's surface, air resistance when the velocity of the rocket is non-axial, and the influence of the Sun's gravitational force. Tsiolkovskii concluded that a rocket should be launched at an angle of 10–20° to the horizontal with the assistance of an automobile, aeroplane or airship, etc.; in another section he suggests that this launching should take place up an incline 500 km. in length, the 20 metres-long space-rocket being made the payload of a kind of rocket sled over 100 metres long. While the construction of such a ramp would by no means be beyond our engineering abilities, it would be a task comparable only to the construction of the Egyptian pyramids by the slaves of long ago. Fortunately space travel is not so difficult to accomplish as some of the most devoted interplanetary[1] enthusiasts sometimes appear to make out.

VIII. Theory of Cosmic Flight

In this, the most bulky book of the nine volumes, Rynin has collected together the classic works of astronautics. Most of them have been translated from German, French or English, but there are also short articles by two other Russians. In addition, short biographies are given of these and some other pioneers. As the works translated are available in their original versions, they will not be discussed in detail here; a brief indication of the contents will suffice.

Rather appropriately, the first pioneer to receive mention is M. Robert Esnault-Pelterie (who is, of course, an Honorary Fellow of the B.I.S. and who presented these books to the Society). In his bibliography it is stated that he was born in Paris on November 8, 1881, and was educated at the Janson de Sailly school up to 1898 and then at the Sorbonne. His work in the field of aviation began in 1900, leading to the construction of a monoplane in 1907. In 1927 he was associated with André Hirsch in the establishment of a prize for work in Astronautics, and he himself was responsible for many publications on this subject. Three of these are given here:—

1. "Considération sur les résultats d'un allégement indefini des moteurs" (1913). Mathematics of rocket flight, with calculations for journeys to the Moon, Mars, and Venus.
2. "L'exploration par fusées de la très haute atmosphère et la possibilité des voyages interplanétaires" (1928). Motion of a rocket *in vacuo* and in

an atmosphere, optimum conditions, behaviour of rockets of various shapes, air resistance, possible uses of the rocket, conditions necessary for carrying living creatures, temperatures at various points in space, physiological effects of zero gravity, control of the rocket, possibilities of life on other planets.

3. "Astronautik und Relativitätstheorie" (1928). An article on relativity theory which was first published in the journal *Die Rakete*, having been translated from the French by Winkler. It later appeared in Esnault-Pelterie's book *L'Astronautique*.

Robert Goddard's work is the next to be considered. Goddard was about a year younger than Esnault-Pelterie, having been born on October 5, 1882. Rynin has translated his celebrated *A Method of Reaching Extreme Altitudes* (1919); the translation is not verbatim, but in addition he gives some artists' interpretations of Goddard's spaceships, and an account of the various patents granted to him. Included as an appendix, is a paper by G. Hamel extending Goddard's work by use of the calculus of variations.

No volume of this nature would be complete without reference to the contributions of Professor Hermann Oberth, another B.I.S. Honorary Fellow. Born in 1894, Oberth was appointed a Professor at Mediasch in Roumania in 1925, after having studied medicine, physics and astronomy. His first astronautical work, *Die Rakete zu den Planetenräumen*, was published in 1923, but is better known to us by the title of the third (1929) edition, *Wege zur Raumschiffahrt*. Rynin mentions that a Russian translation of this edition had already been published. Oberth was responsible for the technical side of the UFA film, "Frau im Mond," made in 1929, and in that year was also awarded the first Rep-Hirsch prize. His subjequent career is well known. Rynin gives here an account of the second (1925) edition of Oberth's book.

The first section is concerned with the theory of rocket flight, and follows the usual course in considering the equation of motion, air resistance, etc. Oberth also deals with the calculation of exhaust velocity, orbits of a rocket in free flight, step-rockets, the use of airships for launching rockets at a great height, and reasons for using alcohol rockets at low altitudes, but hydrogen rockets at greater heights. The second section is a detailed account of a design for a two-step rocket 5 metres long (excluding fins). The first step would use alcohol and liquid oxygen as propellants and would entirely enclose the second step, propelled by hydrogen and oxygen. The total height reached would be 1,960 km. and the time of flight from launching to the return to the Earth's surface would take 35 min. Section three considers the physical and physiological effects of abnormal gravity, a design for a passenger rocket, Oberth's comments on Goddard's work, and his reply to criticisms of his work voiced after the publication of the first edition. Oberth's article in the collective work *Die Möglichkeiten der Weltraumfahrt* (1928), is briefly mentioned; it gave some constructional details for a rocket to be fired to a height of 50 km.

Walter Hohmann, who was awarded the second Rep-Hirsch prize (in 1929), was another German pioneer. Born March 18, 1880, he practised as a civil engineer, became interested in interplanetary travel in 1914 and published

Die Erreichbarkeit der Himmelskörper in 1925. Rynin has translated this book, which is concerned with the mathematics of space travel. Its five chapters are entitled "Ascent from the Earth," "Return to the Earth," "Free Flight in Interplanetary Space," "Flight around other Heavenly Bodies," and "Descent on Other Heavenly Bodies." Translations of two mathematical papers by Hans Lorenz follow: "Die Möglichkeit der Weltraumfahrt" (*Z.V.D.I.*, May 7, 1929, No. 19, p. 651), and "Die Ausführbarkeit der Weltraumfahrt" (*Jahrbuch der Wissenschaftlichen Gesellschaft für Luftfahrt*, 1928, p. 55).

Among the Russian writers on astronautics was Aleksandr Borisovich Shershevskii, who was born in Leningrad on October 22, 1894. He studied mechanical engineering, naval construction and aeronautics and worked in an aviation factory in 1916–17, but later moved to Berlin. There, in addition to various contributions to technical journals, and the Russian section of a multilingual dictionary, he wrote a popular book, *Die Rakete für Fahrt und Flug: Eine allgemeinverständliche Einführung in das Raketen-problem*. He also worked with Prof. Oberth, and included here is a translation of the non-historical part of an article, "Interplanetary Vessels," which he wrote for *Flugsport*, 1927, p. 386; it deals with the mathematics of flight from centrifugal machines and guns, reactive propulsion, air resistance, and spaceship design. A short paper by Julius Kunz (*Die Rakete*, January 15, 1938) is also mathematical, but deals only with the Earth-Moon flight.

After very brief biographies of Ing. Guido von Pirquet (born 1880), Dr. Karl Debus (September 10, 1891) and Willy Ley (October 2, 1906), there follows an article by a Frenchman, Maurice Roy (translated from *La Technique Aeronautique*, January 15, 1930), discussing the gas-turbine engine. The remaining pages of the book are purely Russian: a letter from Yu. V. Kondratyuk (author of yet another book on space travel), a paper by P. N. Lebedev on the determination of the pressure of light on solid bodies and gases, and four pages by Rynin himself. These are concerned with the effect of acceleration upon animals, and give the results of certain experiments made in 1930 and reported in full in Bulletin No. 1 of the State Air Force Institute, Leningrad (Institut Grazhdanskogo Vozdushnogo Flota). Two centrifugal machines were constructed: one of radius 1 metre being capable of up to 300 r.p.m., the other of radius 0·32 metres and capable of up to 2,800 r.p.m. Small animals were placed in these and subjected to rotation for various periods. It is easy to calculate that these machines would exert maximum accelerations of 100 *g* and 2,800 *g* respectively.

From these experiments the following general conclusions could be drawn:—

1. The larger and heavier the animal, the less it withstood acceleration.

2. The duration of the acceleration greatly influenced its effects. This was less noticeable with frogs and birds than with mice, rats, rabbits and cats.

3. Insects, fish and frogs can withstand continued exposure to 2,200–2,500 *g*.

4. The endurance of animals is greatly dependent upon their method of accommodation in the chamber, in the sense of the uniformity of the pressing of their bodies to the external wall of the container. For example,

the immersion of the crucians and frogs in water improved their resistance in general; usually eggs resisted better in water than without water, better in salt water than in fresh, and in sand still better. Mice resisted better in cotton-wool than without it.

5. Experiments with frogs showed that identical centrifugal forces can have different effects on them according to their method of production: a high rotation rate and small radius, or *vice versa*. However, this conclusion still needs verification on other animals, particularly concerning the relation between the size of the animals and the radius of rotation.

The reader may be amused by these experiments, but think that they have little relevance to astronautics. This is not the case; they have relevance both now and in the future. Rynin himself pointed out that they gave useful material for when the time came to construct much larger centrifugal machines for use in experiments with human beings. Such machines have, of course, since been constructed and used in many countries. However, similar experiments are still made upon animals; thus, pigs have been used in tests with rocket-propelled sleds. The information obtained helps in the design of aircraft and aeronautical equipment.

Rynin's experiments with insects and other small animals provide evidence, as he points out, that acceleration is least withstood by the larger animals. This is in accord with our own experience: insects are little affected by sudden shocks and are quite robust, but the largest animal—the whale—is rapidly killed by only 1 *g* (its own weight) if unsupported by water, despite its ability to withstand appreciable hydrostatic pressures. Evidently, if any vermin are present on a spaceship they might well resist the rigours of the journey better than the human crew; bacteria will have an excellent chance of survival as far as acceleration is concerned. While these matters are only of secondary importance where a base on the Moon is concerned, it is obviously undesirable for terrestrial species to be indiscriminately transported to any planet capable of supporting life. The history of the rabbit in Australia is sufficient proof of this. On the other hand, if colonies are ever set up on these planets and it is decided to introduce, under strict control, stocks of farm animals for their use, it will then be necessary to know how these will fare on the journey. Even the experiments on eggs fit in here, for it would probably be more convenient to take some incubating eggs to the Moon than fully-grown chickens.

IX. Astronavigation: Chronicle and Bibliography

The final volume, after prefaces, acknowledgments and other introductory matter, may be considered to consist of five parts. The first deals with the motion of the heavenly bodies, starting with that of the Earth. This involves discussion of the Seasons, the Zodiac, the Ecliptic (the Sun's apparent path through the constellations of stars), celestial co-ordinates and the measurement of time. An account of the Moon's motion naturally follows, accompanied by informative diagrams which make clear the various component movements of our satellite, and the relation of its orbit to that of the Earth. Indeed, the whole chapter is well provided with diagrams, showing in turn the orbit of each

planet (in "plan" and "elevation") in relation to the Earth's orbit. Photographs of some of the planets, maps of the Moon and Mars, and tables of data for the planets, their satellites, the asteroids, comets, meteors and selected stars are also provided.

The second part is concerned with gravitation, and thus covers Newton's explanation of planetary motion, gravitational forces for the various planets and the velocities needed for certain orbits connected with these planets, work required to overcome gravity, etc. A most interesting feature of this chapter is a nomograph constructed to enable one to read off the gravitational force exerted at any selected distance from the centre of a body of any selected mass, values for the Earth, Moon and planets being indicated on the scales for convenience (convenient that is, for those who know the ancient symbols for the planets—the symbols also used by the alchemist to denote the common metals). Rather out of place in this part of the work are a few paragraphs giving the results of Esnault-Pelterie's calculations of the temperature in the region of some of the planets.

The third part—the Chronicle—is a chronological list of works on interplanetary travel (including both technical books and articles and fiction or mythology). It begins with references in Indian manuscripts to Atlantean flights on reaction-propelled aeroplanes from 4,000,000 B.C. to 9500 B.C. and ends with papers published in 1932 by Crocco, Pendray, Tsiolkovskii and others. It would be tedious to single out individual items for comment, but Rynin's statistical analysis is worth quoting as an indication of the growth of interest in astronautics (but one must bear in mind that the earliest items are mainly mythological). Up to the beginning of the Christian era there were 32 items, from thence up to the 17th century 18 items, and in the 17th, 18th, 19th and 20th centuries there were 30, 19, 144, and 1,140 (at the time of writing) items respectively. A more detailed analysis of the references for the 20th century gave the following figures: 1900–09, 63; 1910–19, 131; 1920, 14; 1921, 12; 1922, 12; 1923, 41; 1924, 66; 1925, 57; 1926, 86; 1927, 108; 1928, 205; 1929, 121; 1930, 126; 1931, 85; 1932, 13. The figures for 1929 onwards were incomplete. At first sight one is struck by the fact that the largest number of items mentioned as appearing in any one year (205) is nearly as great as the number of papers abstracted in the *B.I.S. Journal* for 1955 (254). This might be thought to indicate that astronautical activity now is little greater than it was in 1928. However, the two figures are not strictly comparable; B.I.S. Abstracts are meant to survey the cream of astronautical literature, but Rynin's Chronicle also includes references to science fiction novels and films.

A bibliography of the more recent works on astronautics forms the fourth part of the volume. The bibliography is subdivided into five sections, the items in each section being listed alphabetically by authors. The sections are: I. Novels in the Russian language (197 ref.); II. Novels in other languages (81 ref.); III. Cine-films on interplanetary travel (12 ref.); IV. Research and Popular Scientific articles in Russian (447 ref.); V. Research articles in other languages (498 ref.). The references are normally given in the language of the paper concerned. Finally, there are author and subject indexes and a table of contents for the whole nine volumes.

What is to be our assessment of the work as a whole? There are several defects—the most notable being a certain amount of repetition and too great an attention to mythology in some of the volumes. Nevertheless, it certainly represents a great achievement, whether one is considering it as a statement of the position reached by astronautical studies in the 1930's or as a bulky literary work. As an encyclopaedia of astronautics it is still quite unchallenged.

APPENDIX

The bibliographical details of the nine volumes are given below. I am indebted to Mr. Willy Ley for the particulars of the first book, except the price.

I. *Dreams, Legends and First Fantasies.* Published in Leningrad, 1928. x + 110 pp. 82 illustrations, some full-page, but no separate plates. 2,000 copies printed. Price 1 rub. 70 kop. (from later advertisements). Contents range from Icarus, *via* Elijah and Baron Münchaüsen to Camille Flammarion.

II. *Cosmic Ships.* Published by "P. P. Soikin" Publishing House, 8, Stremyannaya Street, Leningrad 25. 1928. 160 pp.; 164 fig. Price 1 rub. 50 kop. (later 2 rub.). 15,000 copies printed. The words "Priroda i Lyudi" (Nature and People) are more prominent on the front cover than the titles of either this volume or the whole set; they appear to be the name for a series of books issued by the publisher.

III. *Radiant Energy.* Published by the author, 37, Kolomenskaya Street, Leningrad 25, and distributed by him and by Izdatel'stvo "P. P. Soikin." 1930 (dated 1931 on cover). 153 pp.; 65 fig. Price 4 rub. 1,000 copies printed. B.I.S. copy inscribed in English on title page: "With compliments from the author, N. Rynin 2 (?)/I, 1931."

IV. *Rockets.* Published by the author, 37, Kolomenskaya Street, Leningrad 25, and distributed by him and by Izdatel'stvo "P. P. Soikin." 1929. 216 pp.; 186 figs. Price 4 rub. 800 copies printed.

V. *Theory of Reactive Motion.* Reprint from *Sbornik Leningradskogo Instituta Inzhenerov Putei Soobshcheniya*, 1929 (101). ii + 64 pp.; 22 fig. Price 1 rub. 50 kop. (from later advertisements). B.I.S. copy inscribed on first page: "With compliments. Monsieur R. Esnault-Pelterie de Professeur N. Rynin. 12/V 29."

VI. *Superaviation and Superartillery.* Published by the author, 37, Kolomenskaya Street, Leningrad 25, and distributed by him and by Izdatel'stvo "P. P. Soikin." 1929. 218 pp.; 200 fig. Price 4 rub. 1,200 copies printed.

VII. *Tsiolkovskii.* Published by the author, 37, Kolomenskaya Street, Leningrad 25. 1931. ii + 112 pp. 39 figs.; 1 plate. Price 3 rub. 50 kop. 1,000 copies printed.

VIII. *Theory of Cosmic Flight.* Published by the U.S.S.R. Academy of Sciences (Izdatel'stvo Akademii Nauk S.S.S.R.), Leningrad. 1932. ii + 358 pp.; 123 fig. Price 10 rub. 1,000 copies printed. B.I.S. copy inscribed on the title page: "Cordially from the Author, N. Rynin 1/III 32.

IX. *Astronavigation: Chronicle and Bibliography.* Published by the U.S.S.R. Academy of Sciences, Leningrad. 1932. ii + 218 + xxii pp. 93 fig. Price 8 rub. 1,100 copies printed. B.I.S. copy inscribed on title page: "Sincerely from the author, 20/V 32."

As mentioned at the beginning of this series of articles, Rynin's conception of the work changed as it progressed. The arrangement above is the definitive one, but the nine books would seem to have been actually issued in the order: I, II, IV and V, VI, III, VII, VIII, IX. Someone (no doubt M. Esnault-Pelterie) has rubber-stamped the covers of the B.I.S. set with the numbers 2–9, corresponding to the following books: II, IV, V, VI, VII, III, IX, VIII. Mr. Ley states that in the first book Rynin intended there to be 4 volumes in 10 parts. The next mention of the plan for the series was in the preface to IV (*Rockets*), which did not refer to any particular order, but indicated that volumes corresponding to VI, VII, VIII, V, and IX were to follow, V being in the press at that date (November 29, 1928). It was also stated that the whole work had then been prepared for publication.

The foreword to book VI, referred to I, II, IV and V as the first four books, and stated that the sixth book (III) was being printed and VII, VIII and IX would follow. In the foreword to III (dated November 1, 1930), a more elaborate scheme is mentioned, the first seven books being I, II, V, IV, VI, III and VII respectively. III and VII were being printed simultaneously. Two other books were ready for the printer, namely: book 9 ("A translation of the 3rd edition of Oberth's *Wege zur Raumschiffahrt*) and 11 (*Bibliography on Interplanetary Travel*). In preparation were books 8 (*Projects of the Scholars*) and 10 (*Elements of Astronomy and Application to Interplanetary Travel*). Evidently 8 and 9 were combined to form VIII, and 10 and 11 to form IX.

By April 1, 1931, when the foreword to VII was written, this scheme had been modified as regards the later volumes. Book 8 was now to be *Theory of Cosmic Flight*, book 9 *Astronavigation*, book 10 the translation of Oberth's work, and *Chronicle and Bibliography* was also to be published. However, the preface to book VIII (dated 1 October, 1931) shows that by then the final plan had been adopted.

HOW BRIGHT IS THE EARTH?

By Alan E. Slater, M.A., F.R.Met.S.

Estimates of what the Earth looks like from outer space are still mostly guesswork, once one gets outside the range of rocket-borne cameras. A coloured model of the Earth was produced in 1930 by the late Howard Russell Butler, a leading American painter of geological and astronomical subjects, and is said to be now in the Butler Memorial Room of the Princeton University Observatory. Two black-and-white photographs of this model[1] show a conspicuous cloud belt round most of the equator, with a few isolated cloud masses elsewhere, irregularly distributed, but the total cloudiness is very much less than the estimate of 52 per cent generally accepted by meteorologists. The oceans appear very dark, probably because the photographs exaggerate the contrasts of the model.

But there is one way of finding the Earth's brightness, and even its general colour, without going outside to look. This is by observing the "Earth-light" which can be seen lighting up the dark side of the Moon when the sunlit portion shows as no more than a thin crescent—a phenomenon known as "the old Moon in the new Moon's arms." One French astronomer, André Danjon, Director of Paris Observatory, and now president of the International Astronomical Union, has been working on these lines ever since 1926, and has recently summarized his conclusions in Chapter 15 of a new book.[2]

It is not too easy to measure the faint earth-light when it is so vastly outshone by the neighbouring bright crescent, and Danjon's best way round this difficulty is to produce two images of the Moon side by side, one of which has been dimmed by reflecting the light through two prisms and cutting it down with a "cat's eye" diaphragm. The dimmed image of the bright crescent is then brought into juxtaposition with the edge of the undimmed earth-light, and the dimming needed to make the two images equally bright is measured by the "cat's eye." Actually two particularly bright spots on the Moon's surface are used for comparison: one is between the Mare Crisium and Mare Fœcunditatis, and the other between Oceanus Procellarum and Mare Orientalis.

Earth's Albedo

Of the total sunlight falling on the Earth, about four-tenths is reflected back into space. Scientifically, this is expressed by saying that the Earth's albedo is 0·40. The albedo of Venus is 0·64—a high value due to its being covered with clouds, whereas the cloudless Moon and Mercury have low albedos of 0·073 and 0·055 respectively.

Danjon's estimate of 0·40 as the albedo of the Earth is, of course, made by measuring the earth-light when the Moon is being lit by that hemisphere of the Earth in which Paris is situated. But the other side of the Earth is believed by

him to be less cloudy, and therefore less bright, because it includes the Pacific Ocean, so he estimates the *average* albedo of the Earth to be only 0·36.

However, the Pacific may not be all that cloudless. The best-known estimates of the cloudiness of different parts of the Earth, which were worked out by C. E. P. Brooks, of the British Meteorological Office, in 1919–21, give an average cloudiness of five to six-tenths over the Pacific—about the same as that for the whole Earth.

A particularly interesting conclusion from Danjon's observations of earth-light is that its intensity varies with the seasons; apparently the Earth is at its brightest from March to June and in October and November, while its brightness is at a minimum from July to September. The Earth's albedo varies correspondingly, the extreme values being 0·32 in July and 0·52 in October.

Again, this is a much bigger variation than that shown in the monthly charts of cloudiness over the whole Earth prepared by C. E. P. Brooks.[3] But Brooks had to work on very scanty data from some parts of the world, and it seems pretty certain that Danjon's method—measuring the light which has travelled from the Earth to the Moon and back—will give the most reliable estimates of the changing brightness of the Earth until cameras can be sent far out into space.

Earth's Colour Index

When Danjon compared the sunlit and earth-lit portions of the Moon with his cat's-eye photometer, he noticed that the earth-light looked bluish and the sunlit crescent reddish. What is more, the blueness of the Earth is found to vary with the seasons in the same way as its brightnesss.

The colour of a star or planet is measured scientifically in terms of a "colour index," which is larger the redder the light, and smaller the more the light is blue or violet. Taking the Sun's colour index as 0·79, Danjon quotes 1·10 for the colour index of the Moon and 1·00 for that of both Mercury and Venus, while that of the Earth, which is bluer than any of these objects, averages only 0·37. More interesting still, he finds the Earth's colour index to vary between 0·06 in October and 0·67 in July and August.

That is, the Earth looks bluer in October, when it is at maximum brightness, than in July and August, when its brightness is at a minimum. This is rather a surprising result, because one would expect most of the blue colour to come from the surface of the Earth, rather than from the white clouds which are mainly responsible for its brightness.

However, Danjon suggests that these seasonal variations in colour are due to "fluctuations in the scattering of very small particles suspended in the atmosphere." He quotes a hypothesis mentioned by S. Fritz, to the effect that only 2·3 per cent. of the sunlight received is scattered by the ground, 9 per cent. by the atmosphere above the ground or above clouds, and a little over 23 per cent. by the clouds themselves. This suggests that the main colour variation is due to changes in the 9 per cent. of light which comes from the atmosphere, but it is difficult to understand why.

Another interesting point is that random variations in the colour of the earth-light are at their greatest when the dark portion of the Moon is lit by only

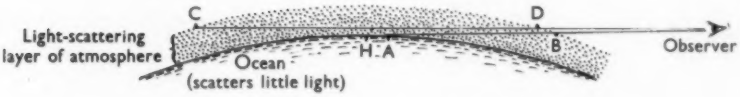

FIG. 1. The "bright band" explained. An observer in space is looking at the edge of the Earth where its surface is an ocean covered with an atmosphere free from clouds. Looking just below the horizon *H*, he sees light scattered from the atmosphere over a distance *A-B*, but just above the horizon the light comes from *C-D*, which is twice as long as *A-B* and therefore scatters twice as much light, giving the effect of a bright band. The drawing is not to scale; the scattering layer is about 7 miles deep.

a thin crescent of sunlit Earth; in practice this means, when observations are made from France, that much of the light comes from the North Atlantic, where the amount of cloudiness is notoriously variable. But the odd thing is that the colour variation is just the opposite to that due to seasonal changes—the earth-light is bluest when the Atlantic clouds are fewest. Can it be that much of the clouded area under these conditions is lit by the setting Sun, so that the total light is redder the more clouds there are?

Rocket Photographs

An interesting contribution to *The Earth as a Planet* is chapter 14, by Clyde T. Holliday, of the Applied Physics Laboratory of the Johns Hopkins University, entitled "The Earth as Seen from Outside the Atmosphere." He writes: "The rocket photographs show that the most striking impression of an outside observer would be the flatness of the earth's surface. The color would be very delicate pastels, predominantly blue-green and red-brown. . . . The highest mountain peak and the deepest canyon would be but minor irregularities on the relatively smooth surface of the earth."

Holliday includes in his chapter eight photographs from rockets high above the Earth, four of which show the same region at the different seasons; not only do the cloud types differ, but the mountain tops are white with snow in Winter but darker than their surroundings at other seasons.

Mr. Holliday draws attention to a bright band (Fig. 1) in the atmosphere just above the horizon, in rocket photographs where the horizon is formed by a cloudless Pacific Ocean. The sea contributes hardly any light, but light is scattered from the overlying atmosphere. Consequently, just above the horizon the camera is looking through a double thickness of atmosphere, because that part of it beyond the horizon is also sending light back to the camera; hence the bright band.

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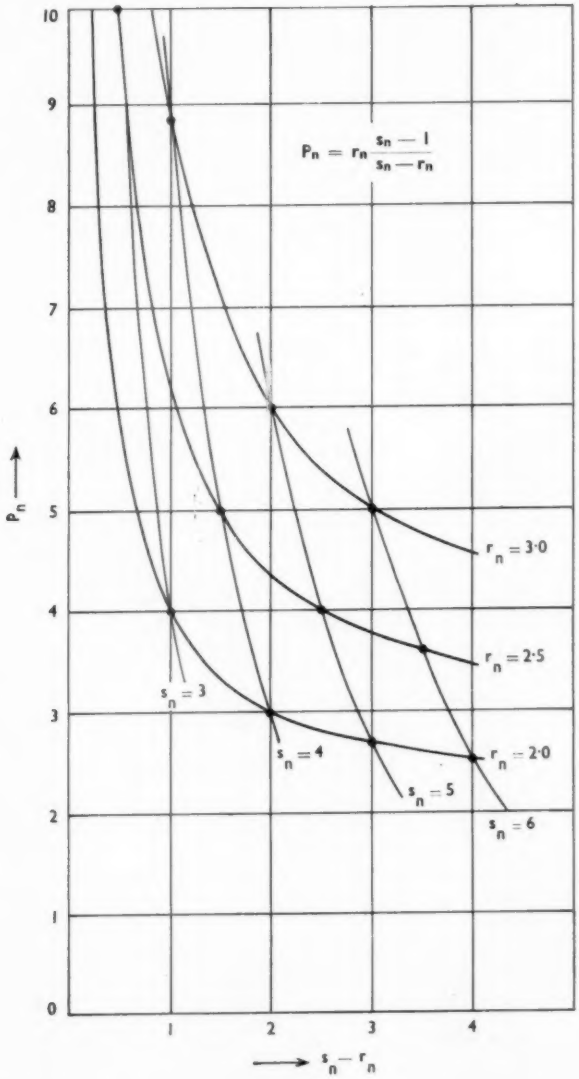

$P_n = r_n \frac{s_n - 1}{s_n - r_n}$
P_n
$s_n - r_n$
$r_n = 3{\cdot}0$
$r_n = 2{\cdot}5$
$r_n = 2{\cdot}0$
$s_n = 3$
$s_n = 4$
$s_n = 5$
$s_n = 6$
0
1
2
3
4
5
6
7
8
9
10

FIG. 1.

A METHOD FOR CALCULATING THE MASS RATIOS OF STEP-ROCKETS*

By M. Vertregt*

If we call: m_{bn} the mass of the propellants of the n^{th} step of a step-rocket
M_n the mass of sub-rocket n of a step-rocket

then: $$r_n = \frac{M_n}{M_n - m_{bn}} \quad .. \quad .. \quad .. \quad .. \quad (1)$$

is the *mass ratio* of sub-rocket n of that step-rocket.

If: r_1 is the mass ratio of sub-rocket 1
r_2 is the mass ratio of sub-rocket 2
r_n is the mass ratio of sub-rocket n

then: $$R = r_1, r_2 \ldots r_n \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

is the *overall mass ratio* of a step-rocket of n steps.

The mass ratio of a rocket is an important figure, as it determines the *ideal velocity* which a rocket can attain in a gravitationless field and without air resistance, according to the equation:

$$V_i = c \,.\, ln\, r \quad .. \quad .. \quad .. \quad .. \quad (3)$$

where c is the velocity of the exhaust gases.

In the case of a step-rocket the ideal velocities of the sub-rockets may be added so that the total ideal velocity of a step-rocket of n steps is given by:

$$\Sigma V_i = c_1 ln\, r_1 + c_2 ln\, r_2 + \ldots c_n ln\, r_n \quad .. \quad .. \quad (4)$$

When the c's are equal for all steps:

$$\Sigma V_i = \phi \,.\, ln\, r_1 \,.\, r_2 \ldots r_n = c \,.\, ln\, R \,. \quad .. \quad .. \quad (5)$$

It is evident that the same product R can be obtained by an unlimited number of sets of the factors $r_1, r_2 \ldots r_n$, but it will be shown that only one set will give the minimum mass of the complete step-rocket.

If we call: m_p the payload
m_{cn} the dry mass of the nth step
and: p the *payload ratio*

$$p_1 = \frac{M_1}{m_p} \qquad p_n = \frac{M_n}{M_{n-1}} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6)$$

and: s the *structural ratio*

$$s_n = \frac{m_{cn} + m_{bn}}{m_{cn}} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (7)$$

then it can be proved that:

$$p_n = r_n \cdot \frac{s_n - 1}{s_n - r_n} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (8)$$

* For notations used in this article, *see* "Calculation of Step-Rockets," M. Vertregt, *J.B.I.S.*, **14** (20), 1955.

Thus p_n is proportional to r_n and inversely proportional to the difference $s_n - r_n$. From this it is clear that p_n will increase rapidly when the difference $s_n - r_n$ becomes smaller; *see* Fig. 1.

In order to keep the payload ratio (and consequently the total mass) of a rocket as low as possible, a low structural ratio of a step should be combined with a low mass ratio of the corresponding sub-rocket.

Generally the structural ratios of the steps of a step-rocket will not be equal. The lowest step will mostly be equipped with stabilization fins which increase the structural weight and decrease the structural ratio, and the highest step in a small step-rocket, for instance the MOUSE, will be so small that optimum structural proportions cannot be obtained.

Therefore it is of importance to dispose of a method for calculating the most favourable mass ratios which agree with these varying structural ratios.

If we call P the *overall payload ratio*

$$P = p_1 . p_2 \ldots p_n = \frac{M_n}{m_p} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

then:

$$P = R . \frac{s_1 - 1}{s_1 - r_1} . \frac{s_2 - 1}{s_2 - r_2} \ldots \frac{s_n - 1}{s_n - r_n} . \quad \ldots \quad \ldots \quad (10)$$

$$(R = r_1 . r_2 \ldots r_n) .$$

Now the problem is to find a set of values for $r_1, r_2, \ldots r_n$ for which P is minimum, with the additional condition, that these values must satisfy the equation:

$$\Sigma Vi - (c_1 ln\, r_1 + c_2 ln\, r_2 + \ldots c_n ln\, r_n) = 0 \quad \ldots \quad \ldots \quad (11)$$

To solve this problem we can use Lagrange's multiplicator-rule.

Call equation (10): $f(r_1 r_2 \ldots r_n)$.

,, ,, (11): $F(r_1 r_2 \ldots r_n)$.

and put: $\phi(r_1 r_2 \ldots r_n) = f(r_1 r_2 \ldots r_n) + \lambda . F(r_1 r_2 \ldots r_n)$

where λ is a constant.

Now by putting: $\frac{\partial \phi}{\partial r_1} = 0 \qquad \frac{\partial \phi}{\partial r_2} = 0 \qquad \frac{\partial \phi}{\partial r_n} = 0$

we get n equations from which, together with equation (11), the r's, which determine the minimum of P, and λ can be solved.

Thus:

$$\frac{\partial \phi}{\partial r_1} = r_2 . r_3 \ldots r_n (s_1 - 1) . \frac{s_2 - 1}{s_2 - r_2} \ldots \frac{s_n - 1}{s_n - r_n} \ldots \frac{s_1}{(s_1 - r_1)^2} - \frac{\lambda c_1}{r_1} = 0.$$

or: $$r_1 . r_2 . r_3 \ldots r_n . \frac{s_1 - 1}{s_1 - r_1} . \frac{s_2 - 1}{s_2 - r_2} \ldots \frac{s_n - 1}{s_n - r_n} . \frac{s_1}{s_1 - r_1} - \lambda c_1 = 0.$$

Now: $$r_1 . r_2 . r_3 \ldots r_n \frac{s_1 - 1}{s_1 - r_1} . \frac{s_2 - 1}{s_2 - r_2} \ldots \frac{s_n - 1}{s_n - r_n} = P.$$

Thus:

$$P . \frac{s_1}{s_1 - r_1} - \lambda c_1 = 0 \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

From: $\frac{\partial \phi}{\partial r_2} = 0.$ $P \cdot \frac{s_2}{s_2 - r_2} - \lambda c_2 = 0.$ .. .. .. (13)

From: $\frac{\partial \phi}{\partial r_n} = 0.$ $P \cdot \frac{s_n}{s_n - r_n} - \lambda c_n = 0$ .. .. .. (14)

By dividing equation 12 by equations (13) and (14), we get the equations 15 and 17:

$$r_2 = s_2 - \frac{s_2}{s_1} \cdot \frac{c_1}{c_2} (s_1 - r_1) \quad .. \quad .. \quad .. \quad (15)$$

$$r_n = s_n - \frac{s_n}{s_1} \cdot \frac{c_1}{c_n} (s_1 - r_1) \quad .. \quad .. \quad .. \quad (16)$$

These values can be substituted in equation (11)

$$\Sigma V_i - (c_1 ln\, r_2 + \ldots c_n ln\, r_n) = 0$$

and r_1 can be solved numerically.

A formal solution is possible when all c's are equal. Then we find that:

$$r_2 = \frac{s_2}{s_1} \cdot r_1. \qquad r_n = \frac{s_n}{s_1} \cdot r_1.$$

And:

$$\Sigma V_i = c(ln\, r_1 + ln \frac{s_2}{s_1} \cdot r_1 + \ldots ln \frac{s_n}{s_1} \cdot r_1)$$

$$= c(n \cdot ln \frac{r_1}{s_1} + ln\, s_1 + ln\, s_2 + \ldots ln\, s_n) = c(n \cdot ln \frac{r_1}{s_1} + ln\, s_1 \cdot s_2 \ldots s_n).$$

Call: $s_1 \cdot s_2 \ldots s_n = S$

Then: $\Sigma V_i = c(n \cdot ln \frac{r_1}{s_1} + ln\, S)$

Furthermore: $\Sigma V_i = c\, ln\, R.$

Thus: $n \cdot ln \frac{r_1}{s_1} + ln\, S = ln\, R.$

from which: $r_1 = s_1 \sqrt[n]{\frac{R}{S}}.$ .. .. (17)

$$r_n = s_n \sqrt[n]{\frac{R}{S}}. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (18)$$

In the foregoing we have supposed that the mass ratios and the structural ratios are independent of each other. This is not strictly right.

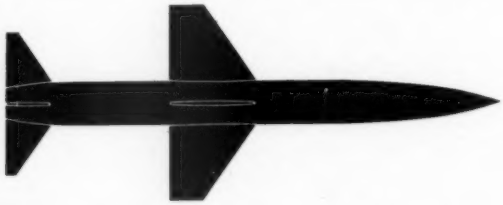
A higher mass ratio will cause higher accelerations and the structure of a rocket must be adapted to withstand the higher forces, caused by these accelerations. Therefore a change in the mass ratio of a sub-rocket will require an alteration of the structural ratios of the corresponding steps. However, for preliminary calculations of step-rockets these formulæ may be useful.

DATA SHEETS

By Kenneth W. Gatland, F.R.A.S.

MATRA M-04 (France)—S.N.C.A. du Sud Est and Société Matra.

(*a*) Role: research, air-to-air; surface-to-air.
(*b*) Origin: 1950.
(*c*) Length: 15 ft. 1 in.
(*d*) Diameter, body (max.): 16 in.
(*e*) Diameter, over fins: not available.
(*f*) Diameter, over wings: 5 ft. 10 in.
(*g*) Weight, launching: 1,012 lb.
(*h*) Weight, propellant: 242 lb.
(*j*) Weight, payload: not available.
(*k*) Thrust: 2,756 lb. × 14 sec.
(*l*) Velocity (max.): 1,100 m.p.h.
(*m*) Altitude: not available.
(*n*) Range: not available.
(*p*) Propellant: not available.
(*q*) Feed system: gas pressure (compressed air).
(*r*) Control: aerodynamic tail-vanes, gyro controlled.
(*s*) Booster: not applicable.



Notes: Two-thirds scale model of anti-aircraft guided missile.

Bi-propellant propulsion unit developed by Société Pour l'Etude de la Propulsion par Réaction.

Several auto-pilots and various wing and tail configurations tested since 1950, when first air-launchings were made.

Matra M-04 believed to be experimental prototype of air-to-air missile for which all new interceptors of French Air Force are provisioned. This weapon, or 1,760 lb. air-to-surface missile, can be carried in ventral bay of S.N.C.A.S.O. Vautour all-weather interceptor.

REFERENCES

(1) *Aviation Week*, April 20, 1953, p. 18.
(2) *Development of the Guided Missile*, by K. W. Gatland (2nd edition, 1954), Iliffe and Sons, Ltd., pp. 84–86; 264–265.

FIREBIRD XAAM-N-1 (United States of America)—Ryan Aeronautical Co.

(*a*) Role: research, air-to-air.
(*b*) Origin: 1950.
(*c*) Length: 7 ft. 6 in.
(*d*) Diameter, body (max.): 8 in. (approx.).
(*e*) Diameter, over fins: 3 ft. (approx.).
(*f*) Diameter, over wings: 3 ft.
(*g*) Weight, launching: 600 lb.
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: not available.
(*k*) Thrust: not available.
(*l*) Velocity (max.): not available.
(*m*) Altitude: not available.

(*n*) Range: 5 miles.
(*p*) Propellant: nitric acid/aniline.
(*q*) Feed system: gas pressure.
(*r*) Control: tail-vanes, gyro controlled/semi-active radar homing.
(*s*) Booster: in-line, solid propellant (length 2 ft. 6 in.)—see Notes.

NOTES: Research vehicle for perfecting techniques of launching, control and guidance. Initial boost supplied by a finless solid-propellant unit forming a streamlined tail, and jettisoned by a charge.

Aerodynamic surfaces arranged in a double-cruciform, the wings assuming an "X" attitude in flight.

Proximity fuse and safety exploder fitted.

Initial trials carried out at Holloman Air Force Base, Alamogordo, with F.82 Twin-Mustang and Douglas B.26.

REFERENCES

(1) *Development of the Guided Missile*, by K. W. Gatland (2nd edition, 1954), Iliffe and Sons, Ltd., pp. 110–111; 258–259.
(2) "Missile Directory," *Aero Digest*, July, 1954, p. 35.

AEROBEE-H1 (United States of America)—Aerojet-General Corporation.

(*a*) Role: research, upper atmosphere.
(*b*) Origin: 1955 (first firing).
(*c*) Length: 20 ft. 9 in.
(*d*) Diameter, body (max.): 15 in.
(*e*) Diameter, over fins: 5 ft. 2 in.
(*f*) Diameter, over wings: not applicable.
(*g*) Weight, launching: 1,220 to 1,300 lb.
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: 120 to 200 lb.
(*k*) Thrust: 4,000 lb.
(*l*) Velocity (max.): not available.
(*m*) Altitude: 180 miles (with 150 lb. payload), 1955.
(*n*) Range: not applicable.
(*p*) Propellant: high concentration nitric acid/aniline.
(*q*) Feed system: chemical gas generator.
(*r*) Control: none, dynamically stable by virtue of three fixed tail fins plus high initial acceleration (approx. 12 *g*).
(*s*) Booster: as Aerobee.

NOTES: Development of original Aerobee with re-designed combustion chamber, improved mass-ratio (e.g., outer shell of thin-gauge stainless steel) and higher concentration nitric acid giving 10 per cent. improved performance. Specification calls for rocket to reach peak altitude of 130 miles with 200 lb. payload; actual performance estimates, based on various payloads, are as follows:—202 miles (120 lb.); 184 miles (150 lb.); and 168 miles (180 lb.).

First two rockets of initial batch of five fired to check performance, without research instrumentation. Twenty-two Aerobee-Hi's scheduled for launching at Fort Churchill, Canada, during International Geophysical Year (July, 1957—December, 1958).

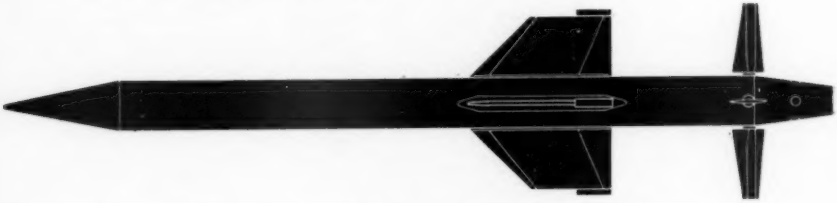
REFERENCE

(1) "New Rocket Boosts Space Research," *Aviation Week*, May 9, 1955, pp. 15–16.

G.P.V. (Gt. Britain)—Royal Aircraft Establishment, Farnborough/Rocket Propulsion Dept., Westcott.

(*a*) Role: research, surface-to-air.
(*b*) Origin: 1950.
(*c*) Length: 25 ft. 4 in.
(*d*) Diameter, body (max.): 17 in.
(*e*) Diameter, over fins: 5 ft. 9 in.
(*f*) Diameter, over wings: 5 ft. 1 in.
(*g*) Weight, launching: not available.
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: various, not available.
(*k*) Thrust: not available.
(*l*) Velocity (max.): Mach 2·5 (cruise).
(*m*) Altitude: not available.
(*n*) Range: not available.
(*p*) Propellant: high test hydrogen peroxide/kerosene.
(*q*) Feed system: gas pressure (applied via pistons in tanks).
(*r*) Control: aerodynamic tail-vanes, gyro controlled/command or beam-rider guidance systems, with semi-active radar homing.
(*s*) Booster: 4-twin "wrapped" solid-propellant units (motor tubes 10 ft. 9 in. × 7 in. dia.; venturi: length 5 in., throat dia. 3 in.; mouth dia. 5 in.).

G.P.V. = General Purpose Vehicle.



NOTES: Development of R.A.E.'s Rocket Test Vehicle 2 (R.T.V.-2) with different motor and internal structure, but dimensionally similar. Manufactured by Short Brothers & Harland, Ltd., under contract with Ministry of Supply.

The following details are applicable to the R.T.V.-2. Component layout, nose to tail: guidance equipment; parachute recovery bay; two spherical pressure bottles (propellant feed); two propellant tanks (for high test hydrogen peroxide and kerosene) comprising heavy cast tube strengthened by annular ribs, with internal pistons acting inwards towards centre of gravity; four wings, square-cut at tips with leading edge sweep (double-wedge section); control bay; hydraulic actuator pack controlling four tail-vanes mounted in line with wings; rocket motor with regenerative cooling.

Details of recovery system (employed when vehicle is tested over water): drouge deploys at velocity of 1,340 ft./sec., main parachute released when velocity has fallen to 400 ft./sec. (Initially, canopy is held closed by spring catches and only released after further decelleration of missile.) Spherical flotation bag ejects when vehicle enters water, inflating under CO_2 pressure to support missile with nose approximately 3 ft. above surface. With recovery bay fitted, missile's overall length is increased to approximately 30 ft.

REFERENCE

(1) "Britain's Guided Missiles," by K. W. Gatland, *R.A.F. Flying Review*, September, 1955, pp. 34–36.

Silhouettes by M. F. Allward

LIGHT AND SHADE ON THE MOON

By Dr. H. P. Wilkins, F.R.A.S.

The time is approaching when men will land amid the weird landscapes of the Moon and, among other strange things, will experience a remarkable sequence of light and shade. It is known that any atmosphere must be of extreme tenuity; even from the Earth we can see the blackness of the lunar shadows, an indication of the rarity of the atmosphere because there is no scattering and diffusion of light as occurs on the Earth.

Yet, despite the deepness of the shadows, the distribution of light on the Moon is, in some respects, greater than with ourselves. Much would depend upon the location of the observer, who we will suppose is on the side which faces the Earth.

At night the stars must shine with a brilliancy unknown to ourselves and the amount of starlight will be very appreciable. It is nearly lost in the light reflected from the Earth which, as seen from the Moon, would appear as a huge disc, thirteen times as great in area and, when fully illuminated, giving sixty times as much light as the Moon does to ourselves. For an observer situated in what is to us the centre of the Moon's disc, the Earth would be overhead and as one travelled north or south or east or west so would the Earth appear to sink in the sky until it would touch the horizon. This would be the state of things for anybody situated at what is to us the edge or limb.

Although the Earth would not remain exactly fixed in the lunar sky, its movements would be small and only noticeable for places where our planet was near the horizon. There is a zone in which the Earth is sometimes visible and at other times invisible, what we know as the libratory regions, bordering the mysterious hidden side of the Moon.

Imagine an observer placed at neither the centre or the edge of the Moon but at an intermediate point; let us select the crater of Theophilus. For him midnight would see the Earth in a gibbous phase, like the Moon three days before full and a little more than half-way up the sky. So intense must be the light reflected by the Earth that everything would be brightly illuminated so that the mountains in the centre of the crater and the crater walls would cast black shadows. The Earth is "full" in the "early hours," always remembering that on the Moon the night lasts fourteen times as long as with ourselves.

The actual amount of light reflected by the Earth will vary because of its rotation on its axis and also on account of the variable amount of cloud in our atmosphere. Once in a little over 24 hours there must be a certain falling off in the reflected light, when most of the Earth's disc is occupied by the vast expanse of the Pacific Ocean. On the other hand, when Asia, Africa and Europe face the Moon, these great land surfaces strongly reflect the sunlight into space.

As the night advances the Earth loses its roundness and a dark sickle begins to invade it on one side. Meanwhile, a bright cone of light has made its appearance in the east and this acts, to some extent, in opposition to the light of the Earth. This cone is the Zodiacal Light which is much more intense as seen from the Moon than from the Earth. Eventually the streamers of the Sun's corona mingle with the Zodiacal Light; the mountains cast dual shadows until, suddenly, the first speck of the Sun's disc appears above the dark horizon.

On the Moon the Sun takes about an hour to rise and, for the first few minutes, the small portion visible gives a twilight effect. Also the shadows bear a considerable penumbral fringe owing to the fact that the Sun is a disc and not a point of light. At the same time, a ray of direct sunshine is much more intense than the, by comparison, feeble light of the Earth.

During the lunar morning, and again in the afternoon, the otherwise black shadows, with their penumbral fringes, are partially relieved by reflection from sunlight cliffs and, to a limited amount, by the light of the Earth. The latter, however, rapidly diminishes as the Sun rises higher above the horizon and approaches the almost stationary Earth, now in a crescent form.

There is a certain blue tint to the sunshine since there is no atmospheric mantle to absorb this part of the spectrum as happens on the Earth. Strongly coloured light is experienced only when the Sun is eclipsed by the Earth during what is to us an eclipse of the Moon. Then the predominating hue is red, very intense for those places which are deeply immersed in the Earth's shadow, but fading into a rose tint for other regions.

The lunar rocks will exhibit marked colours because there is no weather to obliterate them and their visibility is affected by the angle of illumination which is always changing on the Moon.

At mid-day at Theophilus there are no shadows, the Sun shines in full strength and so continues until passing the now invisible Earth, when shadow begins to appear along the crater slopes. As the Sun sinks in the sky the shadows increase and the crescent Earth reflects sufficient light to relieve their intense blackness. With the disappearance of the Sun the cone of the Zodiacal Light adds its quota to the light of the Earth, the light of which gets stronger and stronger as the night draws on.

This is the eternally repeated pattern of light and shade on the Moon and the grand result is that the lunar landscape is always illuminated to a greater or a lesser extent. We can easily be misled by the telescopic view, when the apparently intense black shadows suggest a total darkness within them. The truth is that sometimes they are illuminated by many times the

intensity of our moonlight; it is the adjacent directly sunlit portions which make them seem intense.

For Theophilus the night illumination is least soon after sunset, when the Earth is a crescent, and is greatest in the morning "early hours," when the Earth is full, but for other portions of the Moon the distribution is different and may be reversed. On the Moon the only really black places are the interiors of those craters, or the sides of those mountains, from which neither the Sun or the Earth is ever visible. This condition applies to regions close to one of the Poles, especially the South. The most pleasant landing spot for spaceships, from the consideration of the distribution of light, will be near the centre of the disc, and the crater of Ptolemy may well be the spot selected. There the Earth is "full" at midnight, and being always near the zenith its light is always reflected straight on to the surface so that total blackness is unknown both by day and by night.

ANALYSIS OF REPORTS OF FLYING SAUCERS

Reports of unidentified aerial objects (popularly termed "flying saucers") have been received by the U.S.A.F. since mid-1947 from many and diverse sources, and although there was no evidence that the unexplained reports indicated a threat to the security of the United States, it was decided that all reports of unidentified aerial objects should be investigated and evaluated to determine if "flying saucers" represented some unknown technological development.

In order to discover any trend or pattern in the data, and to evaluate or explain any trend or pattern found, the data was recorded on I.B.M. punched cards by means of logically developed forms and standardized evaluation procedures. The original information usually consisted of impressions and interpretations of apparently unexplainable events, and seldom contained reliable measurement. This presented a major limitation in drawing significant conclusions, but did not invalidate the application of scientific methods of study.

The evaluation of sighting reports, a crucial step in the preparation of the data for statistical treatment, consisted of an appraisal of the reports and the subsequent classification of the object or objects described in each report, great care being taken to maintain complete objectivity and consistency. An analysis of the refined and evaluated data derived from the original reports consisted of:—

(1) a systematic attempt to discover any distinguishing characteristics in the data;
(2) a concentrated study of any trend or pattern found;
(3) an attempt to determine the probability that any of the reports represent unknown technological developments.

The first step in the analysis of the data revealed the existence of similarities between cases of objects definitely identified and those which were not, and statistical methods of testing indicated a low probability that these apparent

similarities were significant. An attempt to determine the probability that any of the reports were observations of an unknown technological development necessitated a thorough re-examination and re-evaluation of the cases of objects not originally identified, which led to the conclusion that the probability was very small.

The special study which resulted in the present report "Analysis of Reports of Unidentified Aerial Objects, May 5, 1955," was started in 1953. To provide the study group with a complete set of files a cut-off date was established at the end of 1952, up to which time the statistics prepared related to 3,201 reports.

As the study progressed, frequent comparisons were made between the current cases received after January 1, 1953, and those being used for the report. This was done in order that any change or significant trend which might arise from current development could be incorporated in the over-all summary of the position.

The 1953 and 1954 cases show an increasing percentage in the objects identified and decreasing percentages in categories where there was insufficient information and those where the phenomena could not be explained, this trend arising from the improved reporting and investigating procedures.

Official reports on hand at the end of 1954 totalled 4,834. Of these, 425 were produced in 1953 and 429 in 1954. These 1953 and 1954 individual reports were evaluated on the same basis as were those received before the end of 1952, and appear in Table I.

TABLE I

EVALUATION OF 854 "FLYING SAUCER" REPORTS RECEIVED DURING 1953 AND 1954

	Per cent.
Balloons	16
Aircraft	20
Astronomical	25
Other	13
Insufficient information	17
Unknown	9

As the study of the current cases progressed, it became increasingly obvious that if reporting and investigating procedures could be improved, the percentages of those cases which contained insufficient information and those remaining unexplained would be greatly reduced. The key to a higher percentage of solutions appeared to be in rapid "on the spot" investigations by trained personnel. On the basis of this, a revised programme was established by the U.S.A.F.

This new programme, which had begun to show marked results before January, 1955, provided primarily that the 4602d Air Intelligence Service Squadron (Air Defence Command) would carry out all field investigations. This Squadron had sufficient units and was so deployed as to be able to arrive "on the spot" within a very short time after a report was received. After preliminary examination by this Squadron, information was submitted to the

Air Technical Intelligence Centre for final evaluation. This co-operative programme has resulted, since January 1, 1955, in reducing the insufficient information cases to 7 per cent. and the unknown cases to only 3 per cent. of the totals.

The period January 1 to May 5, 1955, accounted for 131 unidentified aerial objects reports received. Evaluation percentages appear in Table II.

TABLE II

	Per cent.
Balloons	26
Aircraft	21
Astronomical	23
Other	20
Insufficient information	7
Unknown	3

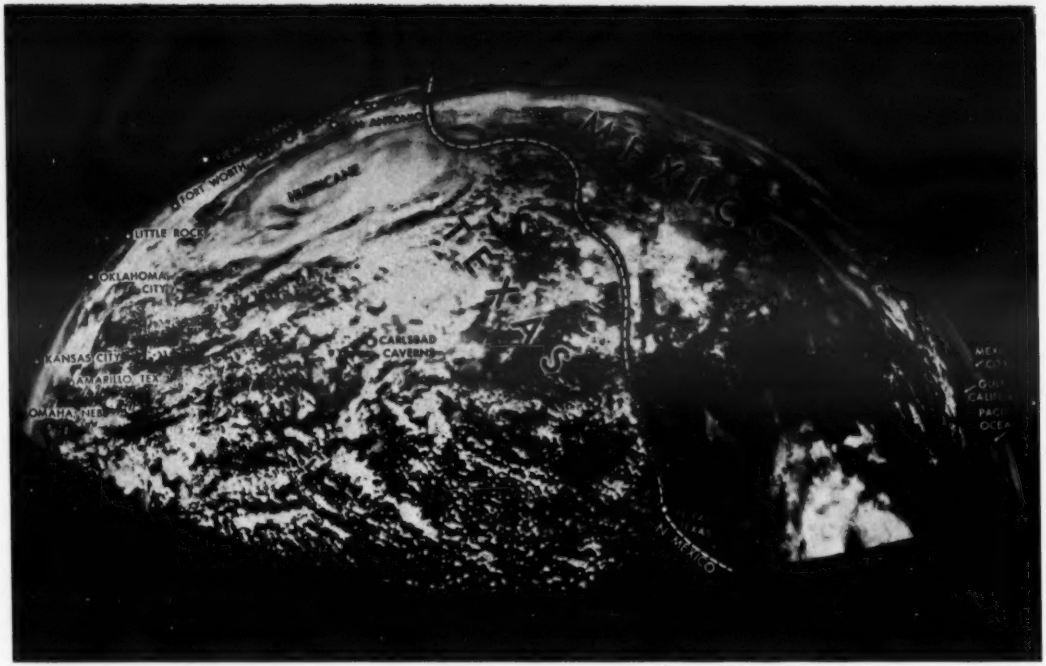
In so far as unexplained objects are concerned, there exists little information other than the impressions and interpretations of their observers. As these impressions and interpretations become replaced by the use of improved methods of investigation and reporting, and by scientific analysis, the number of unexplained cases has decreased rapidly towards the vanishing point, and on the basis of this study, it is believed that all the unidentified aerial objects could have been explained if more complete observational data had been available.

It is considered to be highly improbable that reports of unidentified aerial objects examined in this study represent observations of unknown technological developments outside of the range of present-day scientific knowledge. There has been a complete lack of any valid evidence of physical matter in any case of reported unidentified aerial object.

ROCKET DIVISION OF ARMSTRONG SIDDELEY MOTORS has following vacancies for Mechanical Engineers with qualifications stipulated:—

(1) Mechanical Engineering Graduates or equivalent required for work connected with design and development of test equipment for liquid propelled rocket engines. This work covers a wide range of engineering problems, and offers good prospects to men of the right calibre.

(2) Electronic Engineers for work on design and maintenance of electronic recording gear in connection with testing of engines. Applicants for these positions should hold at least a HNC in Electrical Engineering and have some experience of electronic apparatus. The positions are on the Technical staff and pensionable. Good working conditions. Free transport from Coventry to works and canteen facilities. Applications quoting reference RD/Mech or RD/Elect as appropriate to Technical Personnel Manager, Armstrong Siddeley Motors, Coventry.



Rocket's Eye View

View of the Earth from 100 miles up. Approximately 1·25 million square miles of the World's surface are shown in this composite view—corresponding roughly to two-fifths of the land area of the continental United States. This photograph is made up of 310 prints from a 16-mm. colour motion picture film shot from an Aerobee rocket which was fired by the Naval Research Laboratory of Washington, D.C., at the White Sands Proving Grounds Las Cruces, New Mexico, on October 5, 1954. The Navy believes that this is the largest Earth area ever photographed from one spot at one time. The horizon extends about 2,800 miles—from Omaha, Neb., on the left, to the lower Gulf of California (in Mexico) on the right. Parts of nine states and the whole of Texas is shown. The hurricane in the upper left-hand corner of the photograph is believed to be another first—first complete photograph of a hurricane. It is about 1,000 miles in diameter and is centred near Del Rio, Texas.

TECHNICAL REVIEW

Further News of the IGY Satellite Programme in the U.S.A.

The U.S. Department of Defense has confirmed that work has begun on what is now described as "Project Vanguard," the small unmanned satellite to be launched during the International Geophysical Year, 1957–58, and that several companies are already engaged in building the device. The Glenn L. Martin Co. has been awarded a preliminary contract of $2,000,000 for the design and building of the rocket launching vehicle. The General Electric Company has a sub-contract with Martin for the supply of the rocket motor used in the preliminary stage of propelling this vehicle. The amount of the G.E. contract has not been announced, but "various U.S. sources" state that the motor will be the unit built by G.E. for the Hermes guided missile, and that Vanguard is a "three-stage missile carrying an artificial satellite."

Further information from the Department of Defense indicated that the Pentagon would try and get as many firms as possible a share in the project; Aerojet-General is reported to be under consideration and the firm has stated that it could start immediate construction of a successful space satellite, which may indicate some significant advancements in missile developments: it is possible also that the group associated with the Atlas Intercontinental ballistic missile (Convair on tanks and fuselage, North American on rocket engines, G.E. on guidance, and Ramo-Wooldridge and the Rand Corpn. on systems design) may become involved in the work on Vanguard, which is a joint U.S. Army-Navy-Air Force project, managed by the Navy.

It was stated that "the first rocket will start the entire assembly vertically on the first part of its flight. When its fuel is exhausted, the first stage will drop off, and the second rocket, deflected from the vertical, will continue the satellite upward. The third rocket, carrying the satellite proper, will accelerate it to top speed of about 18,000 m.p.h. which will establish the satellite in its orbit, where it will continue under its own momentum. This high velocity is required to balance the centrifugal force of the satellite against the Earth's gravitational pull. The satellite's orbit will be elliptical and may be 200 miles distant from the Earth at its nearest approach. The satellite will circle the Earth every one or two hours, for several days. . . . The friction of the air as the satellite enters the denser atmosphere will cause it finally to disintegrate in much the fashion of a shooting star."

Besides this official statement more information is available as a result of a joint meeting of the American Rocket Society and the (U.S.) Aviation Writers' Association, where a panel of four scientists discussed the Vanguard project. They were:—Dr. Fritz Zwicky, Professor of Astrophysics at California Institute of Technology and consultant to Aerojet-General; Dr. Milton Rosen, Technical Director for Vanguard; Dr. W. G. Purdy, the project engineer; and A. P. Adamson, manager of General Electric's rocket and ramjet section, and they gave the view that the project will probably consist of ten satellite units, "but enough units will be built to produce at least one successful satellite . . ." but ". . . there are many more ideas of what to do with them (satellites) than can possibly be incorporated in only one satellite."

It was indicated that instrumentation of the satellites will be different from unit to unit. Great effort has been put into the planning of the instruments, and it is likely that different telemetering systems will be employed for the various units and for various purposes: this procedure was followed in the Viking high-altitude rocket programme.

Batteries will probably serve as power sources in the initial experiments, although solar energy may come into use later on: it was suggested that although batteries were reliable and adequately long-lived, the need for weight saving would require minaturization to the fullest extent.

The panel, being composed of scientists interested in widely different fields, would not say what they considered to be the "most important task" of the project, but they expected that "we will obtain data on cosmic rays, the solar spectrum, solar energy, high altitude density, the Earth's magnetic field and the aurora. . . . The satellite might be used to study the unique phenomenon of the speed of gravitational interaction." Up to now, it has only been possible to measure this speed indirectly, with an accuracy of 50 per cent. (*Note*:—The Glenn L. Martin Co. have a contract for the investigation of gravity and other basic phenomena.) The panel could not say what the lifetime of a satellite in the orbit would be, but it might have a lifetime of "perhaps four weeks." They also said that the satellites, which were conveniently spherical but might also be used in other shapes, might be illuminated by painting them with substances which would phosphoresce under the ultra-violet rays from the Sun.

An article in *Electronics* of September, 1955, by J. W. Townsend, Assistant Head of the Rocket Sonde Branch of the U.S. Naval Research Laboratories, lists the author's guesses at the features of the satellites' electronic equipment as:—

(1) Dry batteries (silver or mercury cells) would be used rather than solar sources.

(2) If the satellite has an orbit over 250 miles above the Earth's surface, it would telemeter data for three to five minutes during each 90-minute orbit.

(3) The telemetry and tracking systems would be combined, with the tracking operating continuously.

(4) Telemetry will need a lot of electrical power.

(5) Tracking will be low-powered and work on a narrow band width.

(6) The payload may include photon counters, geiger counters, magnetometers, electrostatic analysers and associated amplifiers, and scaling circuits.

(7) The telemetry could be a.m., f.m. or pulsed.

(8) The tracking and ground equipment may be conventional (and classified).

(9) Computing mechanisms will have a big part in the accurate tracking of the satellite and may detect the reduction (if any) in the orbital velocity.

(10) Because of the high intrinsic resolving power of an optical system, optical tracking may prove more reliable and accurate than radar scanning.

K. R. Stehling, of Bell Aircraft Corp., writing in the *Jet Propulsion* for November, 1955, points out that apart from the usual troubles that beset new missiles, the satellite will present the following posers:—

(1) Orbit perturbation by the Sun and Moon (small).
(2) Orbit perturbation by the oblate shape of the Earth.
(3) Collison with micrometeors (*and* macrometeors!).
(4) Interaction with the magnetic field of the Earth (perhaps not negligible for a metallic body travelling at about 24,000 ft./sec.).
(5) Cosmic ray and solar radiation damage to valve filaments and transistors.
(6) Maintenance of a heat balance within the satellite.
(7) A means of reliable altitude control, either by gyroscopes, flywheels, or control jets.
(8) Recognition of its instaneous attitude and altitude, necessary for proper measurement and interpretation of cosmic ray data, etc.
(9) Circumvention of telemetering signal attenuation by the ionosphere.
(10) If it is desired to recover the satellite rather than let it burn out, it might be possible to coat it with insulation material, but it is possible that the satellite might then be destroyed by the action of aerodynamic forces.

Other Satellite Work

The U.S.S.R. is believed to have a satellite project under the direction of Professor P. Kapitza, but there is not much else available, except that the propulsion and airframe and other parts are to be controlled by General A. S. Yakovlev.

Research Rockets and Firings

What is described as a new altitude record for a "single-stage" rocket has been made by an Aerobee-Hi, which reached 180 miles with 150 lb. of instrumentation. It must be assumed that, if Aerobee-Hi has a boost motor, this is not counted as a stage in this report!

"Rockair" firings in aid of cosmic-ray studies have been made at Chincoteague, Va. The rockets were launched vertically from an aircraft at 30,000 ft. and reached 17 miles.

A programme of IGY rocket firings by the U.S.A. appears to include 36 Aerobees (25 at Churchill, Canada, and 11 at Alamogordo, New Mexico), 37 Rockoons (Thule, Greenland, Churchill and Alamogordo) and an undisclosed number of Rockair in Alaska, Greenland and Newfoundland. It is stated that the U.K. IGY programme will include the firings of solid propellant rockets from balloons at 70,000 ft., rising to 300,000 ft. using a single-stage rocket. Firings will be made from Woomera, and possibly over the South Pole.

An Aerobee firing on February 21, 1955, has given much new data about the ultra-violet solar spectrum. During the entire flight of the Aerobee, which reached an altitude of 78 miles, a spectograph was pointed at the Sun. A continuous spectrum to 1550 A. and absorption lines to 1680 A. were visible.

English Electric missile showing separation of "wrap round" twin boosters.
Fired at the Woomera range.

Continued flight to target.

In the ultra-violet range of 1817 to 977 A. over 30 bright emission lines of nine elements were recorded: the previous best was three emission lines (hydrogen and two magnesium lines).

Missiles and Rocket Aircraft

An indication of costs of some air-to-air guided weapons was given in the November, 1955, *Jet Propulsion*: the new Sidewinder, developed at N.O.T.S. is stated to cost less than $1,000 in production, while the U.S.A.F. Falcon and U.S.N. Sparrow cost about $10,000 each. All three are rocket propelled, and Falcon is stated to weight 112 lb.

In the U.S.A., the Bell X-2 rocket-powered research aircraft is stated to have a radical change in design from the Bell X-1A and X-1B; it has a Curtiss-Wright fully-throttleable engine, giving up to 15,000 lb. thrust, and uses only a nosewheel undercarriage and skids for the main landing gear. It is expected to fly above 90,000 ft. and at nearly 2,000 m.p.h. This is the second X-2, the first one having exploded just before launching from the B-50 carrier aircraft.

The French Trident (SO-9,000) aircraft, fitted with wing-tip jet engines and a three-chamber rocket motor, has been flown at supersonic speed in level flight and at the end of a climb during May, 1955.

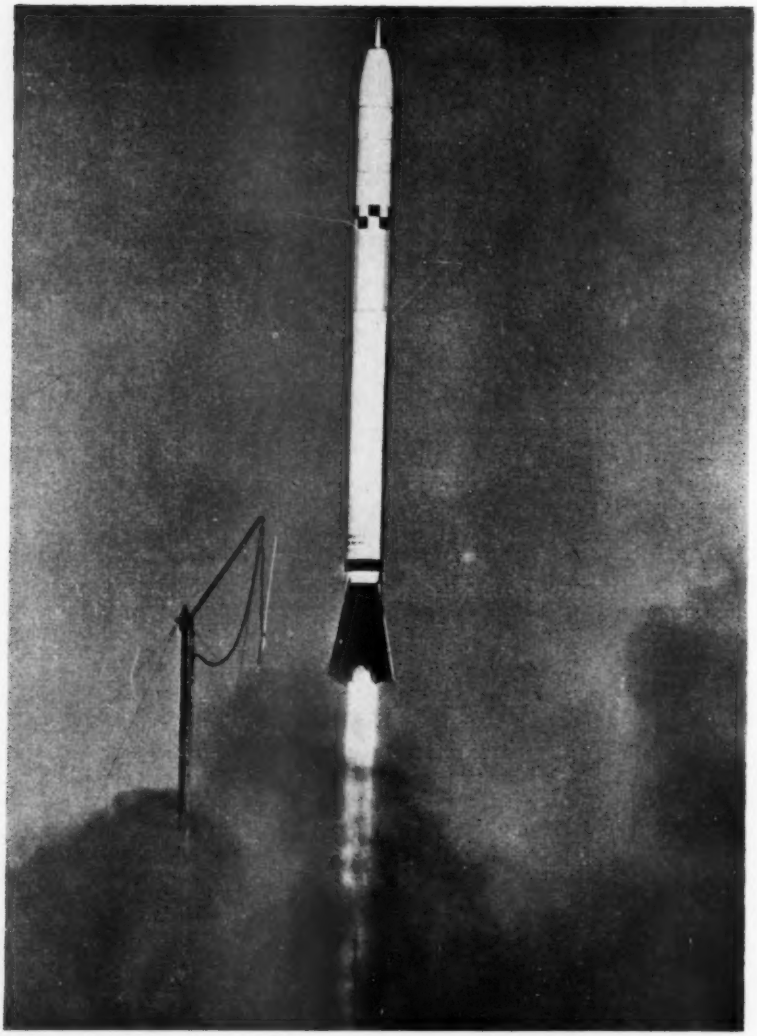
American sources indicate that two rocket-plus-jet interceptors are to fly shortly in the U.K. One has been developed by Saunders-Roe and the other by A. V. Roe. It is claimed that the Saunders-Roe aircraft has a delta wing. The jet-plus-rocket power plant formula has been much in the news lately, particularly in some releases put out by de Havillands and some artists' impressions by Saunders-Roe. The combined power plant for one of these new supersonic interceptors might well be a Gyron or Gyron Junior turbojet with a Spectre rocket engine.

Biological Research

Winzen Research Inc., of Minneapolis, have been sending up balloons with small animals and biological specimens carried in gondolas; the technique is to permit the balloons to reach their ceiling and stay there for a day or so, and then to allow a timer to parachute the gondola to Earth. Reports are somewhat confused, but it appears that in these tests, as well as those made by the Space Biology Branch of the Aero Medical Field Laboratory at Holloman Air Development Center, New Mexico, have shown that even after exposures of up to 35 hours at 120,000 ft., the only significant injury (if it be an injury) was a tendency for black rats to develop white hair. The biological effects of cosmic particles are stated to be no greater than the minimum values expected before the tests, but time must be allowed to see what happens to the most recent test subjects.

Planetary "Weather"

Dr. Jean I. F. King, of the U.S.A.F. Cambridge Research Center, has made mathematical studies of the "weather" on the planets, particularly Mars and Venus. His studies deal mainly with the temperature distributions on these planets, as detected and recorded with astrophysical instruments. Dr. King shows that Mars should have a relatively quiet atmosphere, while Venus should



The Corporal, U.S. Army's surface-to-surface guided missile, just after "take-off" at White Sands Proving Ground, New Mexico.

have violent weather with surface temperatures of several hundred degrees, and with high winds and dust storms.

Although Mars approaches closer to the Earth in 1956 than for many years, and so will enable more detailed observations to be made, nevertheless the turbulence of the Earth's atmosphere will be a severe limitation on the telescopic resolution, and it is proposed that a telescope be sealed into a rotatable gondola, with a large balloon: however, no detailed work appears to have been done so far.

Determination of Sodium in the Upper Atmosphere

Scientists of the U.S.A.F. have fired an Aerobee, which emitted sodium vapour from 40 to 70 miles altitude. The vapour was probably viewed from the ground by spectrograph, and was used to investigate (by comparison of the naturally and artificially induced phenomena) the presence of natural sodium and to determine its density and origin in the upper layers of the atmosphere.

New Establishments for Research and Development on Rocket Motors

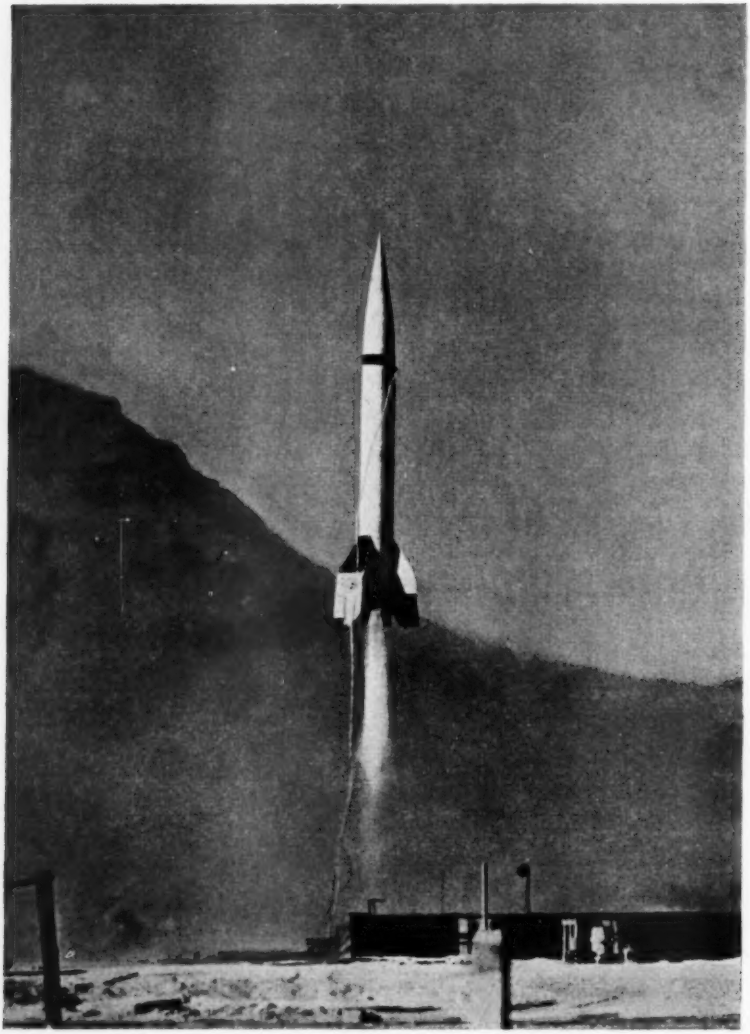
In the U.S.A. one of the two largest rocket plants in the country was opened in October, 1955, by Reaction Motors Incorporated, at Denville, New Jersey. It will probably be used for liquid-propellant engines for missiles and supersonic experimental aircraft. North American Aviation Inc. has announced the establishment of its Rocketdyne Division, as a separate group to carry on continual research, development and manufacture of high-powered rocket engines and related products, to supersede the company's Propulsion Center; presumably the Division will continue to operate at Santa Susana, California. The Company recently signed an agreement with Rolls-Royce for the manufacture of North American-designed rocket engines in the U.K., within the framework of the Collaboration Agreement on guided missiles between the U.K. and the U.S.A. The Rocketdyne Division is headed by S. K. Hoffman, and will employ about 4,000 persons.

In Japan, plans have been disclosed by Prof. Hideo Itokawa of Tokyo University for the establishment of a new permanent rocket centre in N.W. Japan. Construction is to start early in 1956, and it is hoped that the centre will be of use during the IGY. Later it will be enlarged into an institute for basic research for future rocket aircraft.

High-speed Test Tracks

Following on the U.S. Navy's S.N.O.R.T. track at N.O.T.S., China Lake, California, which is used for testing rocket weapons under free flight conditions, the U.S.A.F. has announced that the first rocket test-sled run has been successfully completed at Hurricane Mesa, near Zion National Park, Utah. The track, called SMART (Supersonic Military Air Research Track) is primarily intended for the development of emergency escape techniques from supersonic aircraft. It provides, unlike other tracks, free flight conditions and recovery for equipment tested; the gear is accelerated by a rocket sled and then catapulted over a 1,500-ft. cliff and lowered by parachute to the desert floor.

The rocket sled at Edwards Air Force Base, California, has reached a speed of 1,600 ft./sec. in five seconds, using a two-stage rocket system.



One of America's first supersonic self-launched rockets—the Convair 774—shown during firing at White Sands Proving Ground, New Mexico.
This guided missile was designed and constructed by Consolidated Vultee Aircraft Corporation's San Diego, Californian Division.
The photograph shows the firing cable breaking away from the missile as it begins its ascent. The missile is potentially capable of attaining altitudes of more than 100 miles and speeds far in excess of the velocity of sound.

NOTES AND NEWS

Mr. T. D. Bourdillon's Lecture

It is regretted that Mr. T. D. Bourdillon was not able to give his advertised talk on "Portable Breathing Apparatus" at the Society's meeting on February 4, his place being taken at short notice by Mr. Patrick Moore, who provided a talk on the planet Mars, this being followed by a short Film Show.

However, Mr. Bourdillon has kindly agreed to present his talk following the Society's Annual General Meeting on April 21, 1956.

1956 IAF Congress at Rome

Members who plan to attend the Seventh International Astronautical Congress in Rome on September 17–22, 1956, are invited to communicate with the B.I.S. Secretary.

Enrolment forms have been issued by the *Associazione Italiana Razzi* who have arranged for Compagnia Italiana Turismo to deal with the organization of the hotel and tourist services on behalf of delegates.

It is anticipated that the Technical Papers presented at the Congress will contain some reports of the American Artificial Satellite Programme to be launched in conjunction with the International Geophysical Year (1957–58).

Astronautica Acta

Arrangements have recently been completed whereby the B.I.S. will handle directly subscriptions from members for *Astronautica Acta*, the publication authorized by the I.A.F. to publish Technical Papers presented at Congresses and other papers of an original nature.

Members of the B.I.S. are able to take out subscriptions at a 10 per cent. discount on the normal selling price, and remittances for £3 (which includes postage) should be addressed to the B.I.S. Secretary in connection with subscriptions to commence from 1st January, 1956.

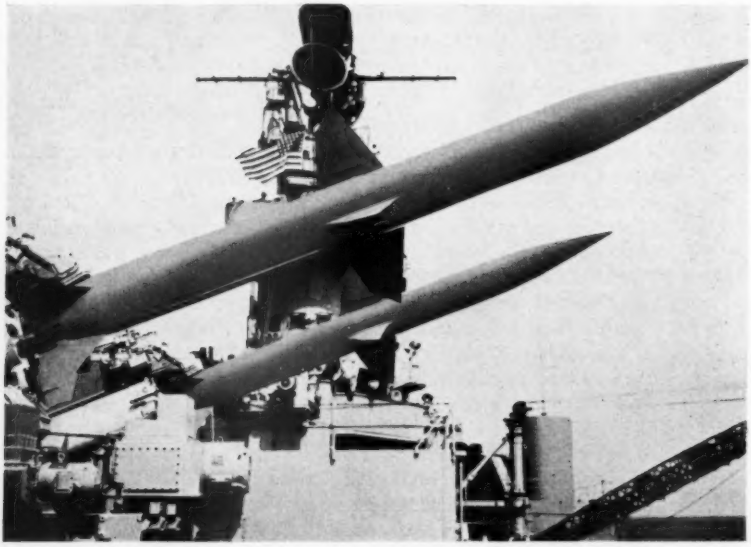
Astronautica Acta is published quarterly, and back issues are also available.

B.I.S. Annual Dinner

About 35 members and guests attended the first B.I.S. Annual Dinner which was held at the Craven Hotel on Saturday, March 17, 1956.

Mr. R. A. Smith welcomed those present in the absence of Dr. L. R. Shepherd, who was indisposed, and said that it was hoped that it would prove possible to continue the Dinner as an annual function on a most informal basis, as this afforded an excellent opportunity for members to get together socially. After the meal a number of films were shown, beginning with *Voyage Across the Impossible*, made as long ago as 1902, and representing the first film to illustrate space flight, although it must be admitted that the idea of an early-type railway engine, complete with half-a-dozen carriages, departing skyward at supersonic speed was not easily digested by those present. The second film concerned the Woomera Base, and showed how the Rocket Establishment was being carved out of the virgin desert. The third film was Dr. Menzel's *Explosions in the Sun*, which included the breath-taking scenes of the largest prominence ever filmed, one which became almost as large as the Sun itself. The final film was in technicolour and featured some of the tests of the Bell X-1A.

The Honest John, U.S. Army's free flight artillery rocket, shown on its tactical transporter-launcher at White Sands Proving Ground, New Mexico.



TTV missile on twin launcher aboard U.S.S. *Mississippi* at sea.

1956 Annual Subscriptions

The 1956 Annual Subscriptions fell due on January 1 and members are asked to remit as soon as possible.

The rates are as follows:—Fellowship, £2 12s. 6d. ($7·50); Membership, £1 11s. 6d. ($4·50); Members under the age of 21 years, £1 1s. ($3·00).

Those members having bank accounts would find it of great convenience to complete and send to their bank the Society's special Banker's Order form, as this would ensure that future subscriptions are paid automatically on the due date. This arrangement also benefits the Society considerably, as it leads to a substantial saving in time and expense.

Members who are able to do so may wish to consider the question of compounding future annual subscriptions by payment of a single lump sum, in accordance with the scale approved by the Council, details of which will be forwarded on request.

Back Issues of B.I.S., A.R.S. and GfW Journals

A few past volumes of *B.I.S. Journals* are available for sale to members at a special price of £1 5s. per volume, post free. Each volume consists of six *Journals* and Index, and these may be sent to the Society's printers, W. Heffer & Sons, Ltd., Hills Road, Cambridge, for binding at a special rate of 9/6 per volume.

The complete volumes still available are as follows:—Vol. 11 (1952), Vol. 13 (1954) and Vol. 14 (1955). In addition, there is a small number of individual issues from previous volumes which are available at a price of 4s. each.

Occasional issues of the *Journal of the American Rocket Society* (later re-named *Jet Propulsion*) can also be obtained at 4s. per copy, and *Weltraumfahrt*—the Journal of the "Gesellschaft für Weltraumforschung e.V."—at 2s. per copy.

Orders and enquiries should be addressed to the B.I.S. Secretary, quoting alternatives where necessary. In view of the small stock held, it is regretted that copies cannot be reserved.

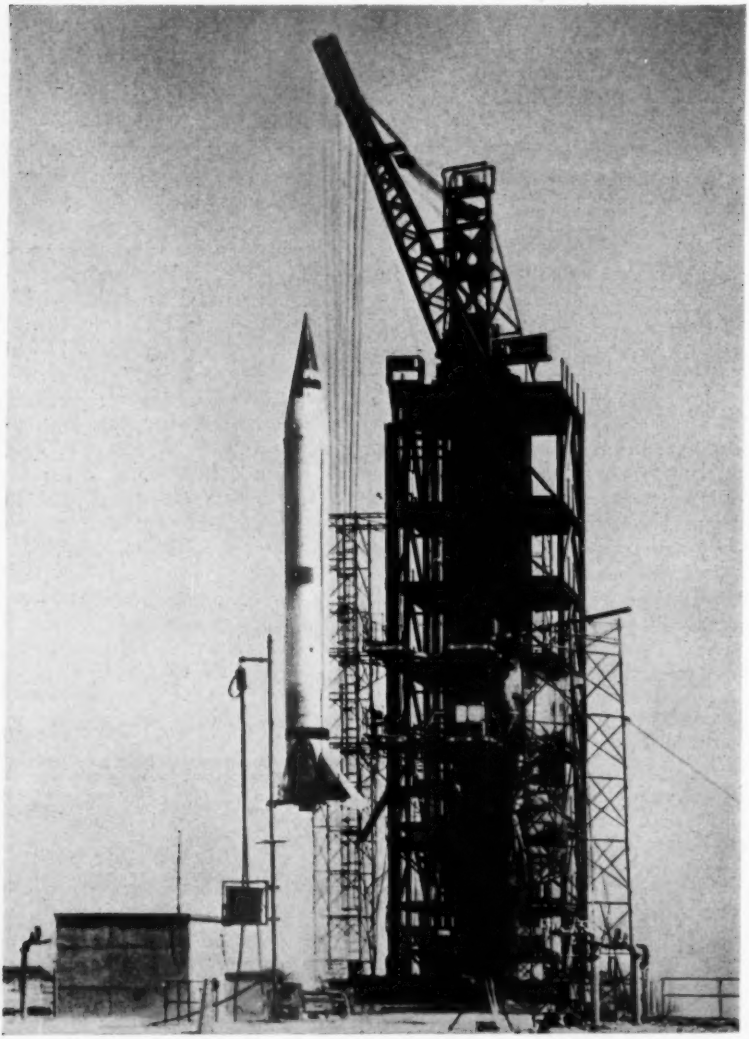
Southampton Meeting

A number of additional meetings were arranged by the Informal Southern Branch during the early part of 1956, beginning with a meeting at the Polygon Hotel, Southampton, on 7th March, when the following papers were read:—

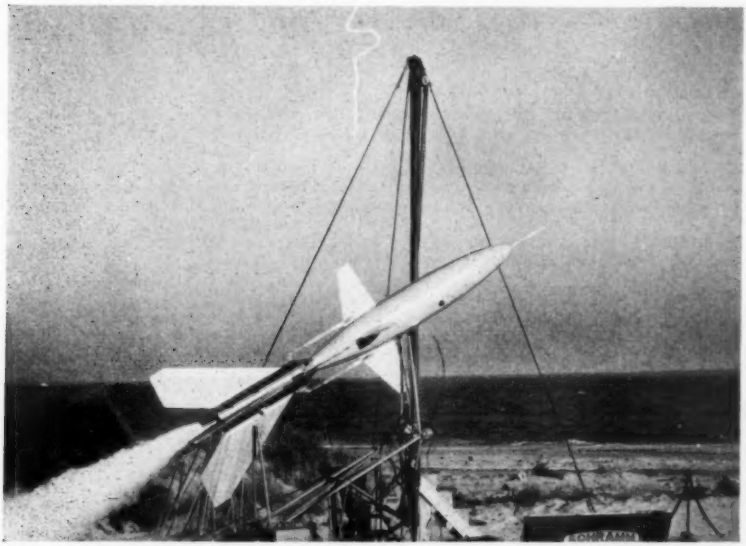
"Space Satellites" by T. J. Smith; "Space Medicine" by D. Jacobs; "Planetary Conditions" by D. H. Penney.

"Reproduced by courtesy of the Editor *De Havilland Gazette*."

A further meeting was scheduled for April 4, and provisional meetings have also been arranged for May 2 and June 6. Full particulars of these meetings can be obtained from the Branch Secretary, Mr. D. H. Penney, 9, Clifton Road, Millbrook, Southampton.



The U.S. Navy Viking 11 leaves its launcher at White Sands, New Mexico, to soar to a record 158 mile altitude and reach a maximum speed of 4,300 miles per hour.



NACA two-stage interceptor missile MX-570 taking off at Wallops Island test station.

The Viking Rocket Story

MILTON W. ROSEN

The full inside account of the epoch-making series of experiments carried out with giant rockets at the White Sands proving ground in New Mexico. The author has recently been designated Technical Director of the sensational earth satellite project—"Project Vanguard." Illustrated with 45 remarkable photographs and 14 diagrams. Price: 21/–

E. T. B. SMITH reviewing the American edition in *The Journal of the British Interplanetary Society*—"A book which should be read by everyone with an interest in rockets . . . the photographs are excellent."

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ABSTRACTS

Edited by J. HUMPHRIES

AERODYNAMICS

(62) **Aerodynamic design of a high-altitude rocket.** A. W. Peppers. *Aero. Engng. Rev.*, **14** (4) 43-7 (*April*, 1955). Design problems of the Viking, including stability, drag and re-entry. A structurally lighter vehicle might be possible if more were known of body pressures. Aerodynamic heating is one of the fields of which there is little knowledge.

(63) **Design charts for transient temperature distribution resulting from aerodynamic heating at supersonic speeds.** J. Kaye and V. C. M. Yeh. *J. Aero. Sci.*, **22**, 755-62, 786 (*Nov.*, 1955). The design charts are based on the analytical solution to the one-dimensional heat flow in a solid body of constant material properties when the boundary conditions are strongly dependent on time. (2 *refs.*)

AIRCRAFT

(64) **The rocket-driven commercial airliner**. W. R. Dornberger. *Interavia*, **10**, 320-3 (*May*, 1955). Proposals for long-range two-stage passenger-carrying aircraft.

(65) **Rocket and turbine engine combination for aircraft.** E. O. Seaver. *U.S. Pat.* 2,713,243 (*July* 19, 1955). Installation of rocket in turbo-jet tail-cone.

(66) **Bell X-2 masks unconventional design.** *Aviation Wk.*, **63** (7) 15 (*Aug.* 15, 1955). Recently released data and photographs.

(67) **Mixed power-plant interceptors.** *Aeroplane*, **89**, 852-4 (*Dec.* 2, 1955). Performance characteristics of aircraft with various combinations of turbo-jet and rocket engines.

ASTRONAUTICS

(68) **Apparent passage of the Earth across the Sun during an Earth-Mars voyage.** G. A. Crocco. *Atti. Accad, Naz. Lincei* (*R.C.Cl. Sci. Fis. Mat. Nat.*), **18**, 245-6 (1955.) (*In Italian*). Possible use of this phenomenon in detecting velocity errors.

(69) **Dynamic problems of interplanetary flight.** D. F. Lawden, *Aero. Quart.*, **6**, 165-80 (*Aug.*, 1955). The general problem of transferring a rocket between two terminals in space with minimum fuel expenditure is explained and the results of a number of particular problems described. Method of obtaining maximum range from a rocket missile over the Earth's surface is given. (16 *refs.*)

(70) **Astronautics at Copenhagen.** A. V. Cleaver. *Aeroplane*, **89**, 231-2 (*Aug.* 12, 1955). General review of the background and opening days of the 6th International Astronautical Congress.

(71) **Larger satellites predicted soon for Government's I.G.Y. proposal.** *Aviation Wk.*, **63** (7), 23-4, 27 (*Aug.* 15, 1955).

(72) **Copenhagen's "rum" week—second report.** A. V. Cleaver. *Aeroplane*, **89**, 274-5 (*Aug.* 19, 1955). Review of some of the papers presented at the 6th International Astronautical Congress.

(73) **Medical and meteorological astronautics.** A. E. Slater. *Aeroplane*, **89**, 276 (*Aug.* 19, 1955). Review of the relevant papers presented at the 6th International Astronautical Congress.

(74) **Earth satellites and the law.** M.Aaronson. *Law Times*, **220**, 115-6 (*Aug.* 26, 1955). Reviews the development of the doctrine that each State has sovereignty over the airspace above its territory. Points out that the treaties and national laws do not refer to outer space and recommends that before implementation of the current Earth satellite projects by the U.S.A. and U.S.S.R. there should be an international conference to define the limits of airspace.

(75) **Influence of space flight on engineering and science.** M. W. Rosen. *Engng.*, **180**, 371-3 (*Sept.* 16, 1955). Lecture delivered to British Association. History of rocketry and possibilities for future with special reference to artificial satellites. (12 *refs.*)

(76) **Influence of space flight on engineering and science.** M. W. Rosen. *Nature*, **176**, 1190–3 (*Dec.* 24, 1955). Substance of lecture delivered to British Association. History of rocketry and possibilities for future with special reference to artificial satellites. (8 *refs.*)

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(77) **The atmosphere of Venus.** *Nauka i Zhizn*, **22**, 30 (1955). (*In Russian.*)

(78) **New light on the changing face of Mars**. E. C. Slipher. *Nat. Geog. Mag.*, **108**, 427-36 (*Sept.*, 1955). An account of the observations carried out by the author during 1954.

(79) **Jodrell Bank symposium on radio astronomy**. B. J. Bok. *Sky & Telescope*, **15**, 21-9 (*Nov.*, 1955).

(80) **Radio emission from astronomical bodies**. A. J. Deutsch. *Leaf. Astr. Soc. Pacif.* (318) (*Nov.*, 1955). A concise survey of the various types of bodies which emit radio waves.

MISCELLANEOUS

(81) **Viking camera and the far west.** *Aviation Wk.*, **63** (9) 53 (*Aug.* 29, 1955). Photo. from Viking 12 taken at 143·4 miles.

(82) **Navy and Reaction Motors open $4-million rocket-engine facility.** H. Lefer. *Aviation Wk.*, **63** (17) 47, 51 (*Oct.* 24, 1955).

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(83) **A study of the mechanism of boiling heat transfer.** M. Ellion. *Calif. Inst. Tech., Jet. Prop. Lab. Memo.* 20-88, 84 pp. (*March*, 1954).

(84) **Ignition and combustion in a laminar mixing zone.** T. Adamson. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 20-79, 117 pp. (*June*, 1954).

(85) **The kinetics of the thermal decomposition of nitric acid in the liquid phase.** G. D. Robertson, D. M. Mason and W. H. Corcoran. *J. Phys. Chem.*, **59**, 683-90 (*Aug.*, 1955). Results in the range 54 to 88° C. and their reference to storage problems. (28 *refs.*)

(86) **Results of a recent attempt to record the solar spectrum in the region of 900-3,000 A.** A. S. Jursa, F. J. Le Blanc and Y. Tanaka. *J. Opt. Soc. Amer.*, **45**, 1085-6 (*Dec.*, 1955). Results from Aerobee flight of March 29, 1955. Seven spectrograms were obtained at heights between 94 and 112 km. (5 *refs.*)

PROJECTILES

See also abs. no. 62.

(87) **Rocket steering means.** E. H. Hull. *U.S. Pat.* 2,692,475 (*Oct.* 26, 1954). Vanes for rocket jet which are internally cooled during use and allowed to burn away when finished with.

(88) **Guided missiles**. G. D. Hinde. *J. Roy. Art.*, **82**, 38-43 (*Jan.*, 1955). General review of requirements and existing vehicles.

(89) **Long-range missiles will make peace unavoidable.** *Interavia*, **10**, 310-3 (*May*, 1955). Military and technical aspects of the intercontinental ballistic missile.

(90) **"Hush, it's top secret."** *Interavia*, **10**, 314-5 (*May*, 1955). Review of Britain's guided missile programme.

(91) **"Nike."** *Interavia*, **10**, 316-7 (*May*, 1955). Operational photos.

(92) **Guidance and control of Swiss (Oerlikon) Type 54 ground-to-air missile.** A. Gerber. *Aviation Age*, 16-25 (*May*, 1955).

(93) **Reliability of guided missiles.** R. Lusser. *RETMA Electronic Applications Reliability Review*, 9-11 (*May*, 1955). Evaluation of fundamental factors, including mathematical concepts, design criteria, fabrication, and a test to failure programme.

(94) **A wider choice of missile control instrument functional characteristics**. B. C. Muzzey and V. J. Sims. *Aero. Engng. Rev.*, **14** (5) 73-6 (*May*, 1955). Description of a rate gyro in which the functional requirements can be specified independently of one another.

(95) **What can electronic simulators do for the missile designer**? F. E. Nixon. *Aero. Engng. Rev.*, **14** (5) 109-12 (*May*, 1955). Application of simulators to interception problems and flight analysis.

(96) **The state of the art.** J. F. Smith. *Interavia*, **10**, 300-9 (*May*, 1955). Review of current missiles with a comprehensive table listing major characteristics.

(97) **Cooling for hypersonic missles sought by N.A.C.A.** I. Stone. *Aviation Wk.*, **63** (3) 36-7, 40, 43, 47 (*July* 18, 1955). Methods proposed have included skin cooling by circulation of a coolant, by transpiration through a porous skin and the use of a thick skin the outer layers of which are allowed to melt. By careful structural design high-temperature areas can also be avoided.

(98) **Rules for guided missile design engineers.** R. Lusser. *Tele-Tech.*, 86-7 (*Aug.*, 1955). Recommended standards based on a concept of absolute reliability.

(99) **U.S. Corporal battalion set to go in Germany.** G. W. Schroder. *Aviation Wk.*, **63** (9) 28-30 (*Aug.* 29, 1955). Description of demonstration "dummy" firing.

(100) **Instruments for guided weapons.** *Aeroplane*, 89, 551-2 (*Sept.* 30, 1955). Accelerometers, gyros, pressure transdiners, etc., developed by Grazeby Instruments, Ltd., specifically for guided missiles.

(101) **Guided missile problems.** W. H. Pickering. *Ordnance*, **40**, 241-3 (*Sept.-Oct.*, 1955). General review of problems in guided missile development.

(102) **Navy Sparrow in first detailed pictures.** *Aviation Wk.*, 63 (17) 21 (*Oct.* 24, 1955).

(103) **Rockets and missiles in Paris.** *Aeroplane*, **89**, 666-8 (*Oct.* 28, 1955). Review of some of the films shown at the AERA meeting, Oct. 14-15.

ROCKET MOTORS

See also abs. no. 65.

(104) **Photographic investigation of combustion in a two-dimensional transparent rocket engine.** D. Bellman, J. C. Humphrey and T. Male. *N.A.C.A. Rept.* 1134, 12 pp. (1953). Motion pictures at speeds up to 3,000 f.p.s. on a liquid oxygen/gasoline 100-lb. motor showed that the flame front extended almost up to the faces of the injectors. Seven injectors showed considerable nonuniformity of combustion. Pressure vibration measurements indicated frequencies corresponding to the resonant frequencies of length and thickness of the chamber.

(105) **A variable delay timer for premixed gaseous propellant rocket engines.** L. Bollinger. *Wright Air Development Center Rept. TR* 53-428, 21 pp. (*Oct.*, 1953).

(106) **Regenerative liquid fuel rocket motor.** R. J. Andrus. *U.S. Pat.* 2,686,400 (*Aug.* 17, 1954). Combustion chamber design.

(107) **Rocket reactant feed system.** R. P. Haviland. *U.S. Pat.* 2,687,168 (*Aug.* 24, 1954). Method of controlling the flow of propellants from two tanks to maintain predetermined mixture ratio. Uses float and series of fixed contacts as the sensing device.

(108) **Tangential sheet cooling of internal-combustion chambers.** R. H. Goddard. *U.S. Pat.* 2,689,453 (*Sept.* 21, 1954). Use of tangential cooling film holes in a spherical chamber.

(109) **Rocket engine.** H. Schneider. *U.S. Pat* 2,689,454 (*Sept.* 21, 1954). System using precombustion chamber ignited by self-igniting propellants, but running on non-self-igniting propellants. Turbine gas taken from precombustion chamber.

(110) **Reaction motor operable by liquid propellants and method of operating it.** F. J. Malina and J. W. Parsons. *U.S. Pat.* 2,693,077 (*Nov.* 2, 1954). Use of a mixture of hydrazine, carbon disulphide and phosphorus with nitric acid.

(111) **Structure for feeding, intermingling, vaporizing, and igniting combustion liquids in a combustion chamber for rocket-type propulsion apparatus.** R. H. Goddard. *U.S. Pat.* 2,695,496. (*Nov.* 30, 1954). Baffle in chamber to produce separate mixing and combustion spaces.

(112) **Combustion instability in rocket engines.** C. Ross and P. Datner. *West. Aviation*, 6-8, 35-7 (*Jan.*, 1955). Experimental study of high and low frequency oscillatory combustion in liquid-propellant engines when the oscillations are sustained by a feedback mechanism represented by the interaction between the rate at which the propellant is consumed and the fluctuations in the chamber pressure.

(113) **Rocket motor.** E. H. Hull and A. F. Winslow. *U.S. Pat.* 2,698,514 (*Jan.* 4, 1955). Injector for hydrogen peroxide and catalyst.

(114) **Ceramic lined, lightweight rocket motor structure and like device.** K. C. Nicholson. *U.S. Pat.* 2,699,036 (*Jan.* 11, 1955).

(115) **Liquid propellant rocket.** J. M. Cumming. *U.S. Pat.* 2,700,337 (*Jan.* 25, 1955). Use of acceleration head to inject propellants into combustion chamber.

(116) **Surge relief system for rocket motor fuel supply system.** S. W. Crawford. *U.S. Pat.* 2,700,871 (*Feb.* 1, 1955). Use of a quick-operating valve and by-pass line.

(117) **Pressurized feed for jet propulsion systems.** H. M. Mitchell. *U.S. Pat.* 2,701,441 (*Feb.* 8, 1955). Evaporation of liquid oxygen in heat exchanger system.

(118) **Ignition equipment for the combustion equipment of rocket motors.** E. G. D. Andrews and A. W. T. Mottram. *U.S. Pat.* 2,701,445 (*Feb.* 8, 1955). Precombustion chamber using main propellants.

(119) **Rocket engine injector head.** D. L. Olson. *U.S. Pat.* 2,703,962 (*March* 15, 1955). Multi-hole "shower" injector

(120) **Experimental rocket engine.** R. Edse. *Ohio State University Engineering Experiment Station News*, 17-8 (*April*, 1955). Engine to develop direct measurement of gas velocity and temperature, both in chamber and at nozzle exit.

(121) **Combustion chambers.** S. Allen. *U.S. Pat.* 2,705,399 (*April* 5, 1955). Use of coaxial rings to construct chamber.

(122) **Devices for confinement and release of high-velocity, hot gases.** I. M. Logan. *U.S. Pat.* 2,706,382 (*April* 19, 1955). Combustion chamber with silicon nitride inner surface.

(123) **Liquid propellant rocket motor**. H. B. Grow. *U.S. Pat.* 2,706,887 (*April* 26, 1955). Combustion chamber with method of producing layer of cool combustion gases near wall of chamber. Utilizes inner cylindrical shell to separate hot and cool zones.

(124) **Mixed fuel control system for a rocket motor.** S. Allen and D. Hurden. *U.S Pat.* 2,708,342 (*May* 17, 1955). Layout for a bipropellant turbo-pump system.

(125) **Method of using a hot vapor igniter.** M. J. Zucrow. *U.S. Pat.* 2,708,341 (*May* 17, 1955). Precombustion chamber system.

(126) **Zonal spray combustion chamber for rockets and rocket craft.** R. H. Goddard. *U.S. Pat.* 2,709,887 (*June* 7, 1955). Method of injecting propellants over complete surface of spherical combustion chamber.

(127) **Mechanism for intermittent feeding of combustion liquids to a combustion chamber in propulsion apparatus.** R. H. Goddard. *U.S. Pat.* 2,709,890 (*June* 7, 1955).

(128) **Burners for use with rocket motors.** Sir W. G. Armstrong-Whitworth Aircraft, Ltd. *Brit. Pat. No.* 731,739 (*June* 15, 1955). A multi-hole type burner of simple construction.

(129) **Rockets.** S. C. Lehman. *U.S. Pat.* 2,711,630 (*June* 28, 1955). Missile with coaxial tanks pressurized by solid charge.

(130) **Rocket engine.** R. L. Schapker. *U.S. Pat.* 2,711,629 (*June* 28, 1955). Turbine wheel in nozzle throat with shaft extending back through chamber head to pumps.

(131) **Control system for a rocket motor.** H. L. G. Sunley. *U.S. Pat.* 2,711,751 (*June* 28, 1955). Propellant control method.

(132) **Double deflecting spray nozzle**. R. H. Goddard. *U.S. Pat.* 2,712,962 (*July* 12, 1955).

(133) **More about the Super Sprite.** *Aeroplane*, **89**, 171-5 (*July* 29, 1955). Full technical details of construction and performance.

(134) **Liquid-propellant injection system for jet motors**. M. J. Zucrow. *U.S. Pat.* 2,714,286 (*Aug.* 2, 1955). Method of staging injection.

(135) **Combustion chambers for rocket motors.** F. B. Halford and A. V. Cleaver. *Brit. Pat. No.* 738,219 (*Oct.* 12, 1955). An inner flame tube contains the high-temperature gases and low-temperature gas flows between this and the outer stress-bearing wall of the chamber.

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REVIEW

The Moon

(By Dr. H. P. Wilkins and Patrick Moore. Faber and Faber. 1955. 388 pp. 63s.)

This book is an important landmark in the development of selenography, and will be welcomed by serious students as a valuable work of reference, combining Dr. Wilkins's 300-in. lunar map with a descriptive text. The text material is arranged in 25 sections, each following the corresponding map sheet, with which it is thus easily compared. Within each section the formations are described alphabetically. In addition to approximately 770 of these major, named, formations, mention is also made of many thousands of smaller associated features. Clefts, grooves and ravines; ridges, domes, mounds and peaks; terraces and landslips; bright or dark spots or patches, dusky bands and similar markings; and new craterlets down to one-tenth of a mile in diameter: all these varied observations testify to the assiduous and long-continued work put in by the authors. Reports of surface changes are also included, with an attempt to sift mistaken observations from those with an objective basis.

The descriptions are commendably free from interpretations, and constitute valuable factual raw material. The abundant detail is presented with a concise and lucid simplicity, well supported by photographs from a variety of sources, and good special feature drawings.

Some of the additional material, such as the appendix on Lunar Photography by E. A. Whitaker, is very welcome, but some strikes a jarring note, e.g., on page 38 ff., where the authors touch on large controversial issues which they have no space to develop. The inadequate case for the volcanic theory, and the cavalier dismissal of the impact hypothesis achieve nothing, and a single-minded adherence to the book's primary function as a reference work would have consolidated its standing.

The selenographical advances which this book demonstrates suggest two ways in which the science is ready to profit from sister studies. First the findings of geomorphology should prove useful. Though its terminology is often inapplicable to the peculiarly lunar landforms, at least a careless transference of terms is to be avoided. For example, a terrestrial "landslip" involves a definite rôle played by water, and some alternative term would be more suitable for lunar features. Again, the use of the term "erosion" on page 24 is not intelligible to the geomorphologist.

A second suggestion is that the accuracy and wealth of detail available is worthy of a higher cartographical standard. The maps could be made far more telling and dynamic with a little more skilled compilation and draughtsmanship.

The book is pleasingly produced in an attractive format, and should prove of great interest to a wide range of readers.

A. COLEMAN.